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Santos Fairview Water Release Scheme

Preliminary Documentation

10-Feb-2023
EPBC 2021/8914 - Fairview Water Release Scheme

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Santos Fairview Water Release Scheme

Preliminary Documentation

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Abbreviations

Abbreviation	Definition
ADWG	Australian Drinking Water Guidelines
AECOM	AECOM Australia Pty Ltd
AF	Assessment Factor
AICIS	Australian Industrial Chemicals Introduction Scheme
ALA	Atlas of Living Australia
ANZG	Australian and New Zealand Guidelines for Fresh and Marine Water Quality
ARI	Average Recurrence Interval
ARMCANZ	Agriculture and Resources Management Council of Australia and New Zealand
AS/NZS	Australian Standards/New Zealand Standards
ASTM	American Society for Testing & Materials
AUSRIVAS	Australian River Assessment System
AWBD	Associated water balance dam
BoM	Bureau of Meteorology
CCS	Carbon Capture and Storage
CEM	Conceptual Exposure Model
CHMA	Cultural Heritage Management Agreement
CHMP	Cultural Heritage Management Plan
CL	Contaminant Limit
CMA	Cumulative Management Area
COPC	Contaminant of Potential Concern
CORMIX	Cornell Mixing Zone Expert System
CRD	Cumulative Rainfall Departure
CRAF	Chemical Risk Assessment Framework
CSG	Coal Seam Gas
CSM	Conceptual Site Model
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAWE	Department of Agriculture, Water and the Environment (Commonwealth)
DCCEEW	Department of Climate Change, Energy, the Environment and Water (Commonwealth)
DES	Department of Environment and Science
DGV	Default Guideline Value
DNRM	Department of Natural Resources and Mines
DNRME	Department of Natural Resources, Mines and Energy
DO	Dissolved Oxygen
DOE	Department of the Environment (Commonwealth – now DAWE)

Abbreviation	Definition
DOEE	Department of the Environment and Energy (Commonwealth)
DOR	Department of Resources
DRDMW	Department of Regional Development, Manufacturing and Water (QLD)
DRRS	Dawson River Release Scheme
DST	Drill Stem Tests
DTA	Direct Toxicity Assessment
DWBD	Desalinated Water Balance Dam
EA	Environmental Authority
EC	Electrical Conductivity
EFO	Environmental Flow Objectives
EHP	Department of Environment and Heritage Protection (former name of DES)
EIS	Environmental Impact Statement
EP Act	*Environmental Protection Act 1994*
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
EPCs	Exposure Point Concentrations
EPP Water	*Environmental Protection (Water and Wetland Biodiversity) Policy 2019*
ESD	Ecologically Sustainable Development
EV	Environmental Value
FAPA	Fairview Arcadia Project Area
FPA	Fairview Project Area
GAB	Great Artesian Basin
GBRMP	Great Barrier Reef Marine Park
GDE	Groundwater Dependent Ecosystems
GFD Project	Gas Field Development
GHD	Gutteridge Haskins & Davey
GHG	Greenhouse Gas
GLNG Project	Gladstone Liquefied Natural Gas Project
GSQ	Geological Survey of Queensland
GW	Groundwater
GWDB	Groundwater Database
HEV	High Ecological Value
HDPE	High Density Polyethylene Pipe
I/LP	Insignificant / low probability exposure
IC	Incomplete exposure
IESC	Independent Expert Scientific Committee
IPCC	Intergovernmental Panel on Climate Change
IQQM	Water Quality & Quantity Simulation Model

Abbreviation	Definition
ISO	International Standards Organisation
KCB	Klone Crippen Berger
MD	Moderately Disturbed
MDC	Referenced section 9.2
MNES	Matters of National Environmental Significance
NHMRC	National Health and Medical Research Council
NOEC	No Observable Effect Concentration
NSW	New South Wales
NWQMS	Australian National Water Quality Management Strategy
OGIA	Office of Groundwater Impact Assessment
PBT	Persistent, bioaccumulative and toxic
PD	Preliminary Documentation
PGDP	Paducah Gaseous Diffusion Plant
PL	Petroleum Lease
PMST	Protected Matters Search Tool
PNEC	Predicted No Effect Concentration
QLD	Queensland
QGC	Queensland Gas Company
QPED	Queensland Petroleum Exploration Database
QWC	Queensland Water Commission
QWQG	Queensland Water Quality Guidelines
RCP	Representative Concentration Pathway
RE	Regional Ecosystem
REMP	Receiving Environment Management Plan
RFI	Request for Information
RO	Reverse Osmosis
ROP	Reverse Osmosis Plant
Santos	Santos Limited
SIA	Social Impact Assessment
SRI	Significant Residual Impact
SSD	Species Sensitivity Distribution
SSWQG	Site Specific Water Quality Guideline
STEM	Science, Technical, Engineering and Maths
SW	Surface Water
TDS	Total Dissolved Solids
TEC	Threatened Ecological Community
TSS	Total Suspended Solids

Abbreviation	Definition
TTPC	Tributyl tetradecyl phosphonium chloride
USD	United States Dollar
USEPA	United States Environmental Protection Agency (under section 8.1.2)
USGS	United States Geological Service
UWIR	Underground Water Impact Report
WASOs	Water Allocation Security Objectives
WHO	World Health Organisation
WTP	Water Treatment Plant
WQO	Water Quality Objective

Units

Unit	Parameter
cm	Centimetres
DO	Dissolved Oxygen
EC	Electrical conductivity
GL	Gigalitre
Ha	Hectare
Km	Kilometre
Km^2	Square kilometres
m	metre
m AHD	metres above Australian Height Datum
mD	millidarcy
mbgl	metres below ground levels
mg	milligrams
mg/L	milligrams per litre
ML	Megalitre
ML/day	Megalitre per day
ML/year	Megalitre per year
mm	millimetres
mS/cm	milliSiemens per centimetre
NTU	Nephelometric Turbidity Unit
L	Litre
pH	Potential of hydrogen
µg/L	Micrograms per litre
µS/cm	MicroSiemens per centimetre
µS	MicroSiemens

Executive Summary

The Fairview Water Release Scheme (WRS and the proposed action) forms a part of the overall produced water management strategy of the Santos Gas Field Development (GFD) Project located within the Arcadia, Fairview, Scotia, and Roma Project Areas within southern central Queensland. The proposed action seeks authorisation for the release of desalinated (treated) water from the Santos Gas Field Development Project (GFD) (EPBC 2012/6615) to the Dawson River. The proposed action is to compliment an existing water management strategy of other beneficial uses (e.g. drip and pivot irrigation, stock watering, and construction and operational uses). The Fairview WRS is required to manage water and support natural gas production beyond irrigation and other beneficial use capacity, including during wet weather events. As a result, the proposed desalinated water release is variable in frequency and duration but released at up to a maximum rate of 18 Megalitres per day (ML/day), including cumulative total with water from the GLNG Project. There will be no increase in the existing maximum daily release or total annual volume of 6,570 ML/year, including cumulatively with the GLNG Project (as limited by the State Environmental Authority conditions).

The Draft Preliminary Documentation (PD) submission (Revision A, 1 June 2022) included a proposed event-based release of produced water in addition to the desalinated (treated) water release. Having been granted State approval for the event-based release in 2016 this was proposed as a contingency option to manage water levels during extreme wet weather conditions. No infrastructure is in place for event-based releases, and the event-based release is not included in any water management plans. As such, Santos requested a variation and has received approval from the Department of Climate Change, Energy, the Environment and Water (DCCEEW) to remove the event-based release, and as such it no longer forms a component of the proposed action.

The proposed desalinated water release to the Dawson River for the GFD Project will be a continuation of existing produced water management practices in Fairview for the Gladstone Liquefied Natural Gas (GLNG) Project (EPBC 2008/4059). The proposed action will include co-mixed water generated from the approved GLNG Project as produced water volumes decline gradually and include produced water generated by the GFD project as wells “come on-line” and generate produced water. No new treatment or other water release infrastructure is required for the proposed action as it is pre-existing for the GLNG Project. Current water treatment includes reverse osmosis (RO) which is a common and established process used to treat seawater and wastewater to potable standards from a household (under-sink) scale to commercial scale as a component for treating wastewater from sewage treatment plants to potable water standards.

The release of desalinated water to the Dawson River for the GFD Project is not authorised by the GFD Project EPBC approval 2012/6615 (condition 2A). This release however does have State approval under the Queensland Environmental Authority EPPG00928713 (State EA). The State EA authorises the release of desalinated water from the GLNG Project and GFD Project up to 18 ML/day via an ephemeral drainage feature and waterhole and subsequently via a short watercourse to the Dawson River.

The proposed action area comprises the stretch of the Dawson River between the desalinated release point at the head of an ephemeral drainage feature (gully) and the existing downstream monitoring location (S4, located at Yebna Crossing), via a waterhole and an outlet watercourse that discharges to the Dawson River via a watercourse.

In March 2021, Santos referred the Fairview WRS and the accompanying Produced Water Releases - Fairview – Assessment of Matters of National Environmental Significance Report (AECOM (2021)) to the Department of Agriculture, Water and the Environment (DAWE – now the Department for Climate Change, Energy, the Environment and Water - DCCEEW) for a decision on whether assessment and approval of the proposed action is required under the EPBC Act. On 7 July 2021, the delegate of the Minister for the Environment determined the Fairview WRS to be a controlled action under Part 3 of the EPBC Act with the following controlling provisions:

- listed threatened species habitat and communities (sections 18 and 18A), specifically potential impacts to the following species and their habitat:
  - White-throated Snapping turtle (*Elseya albagula)*

- Fitzroy River turtle (*Rheodytes leukops*), and

- a water resource, in relation to coal seam gas development and large coal mining development (sections 24D and 24E).

Following the 2021 referral DAWE issued a request for additional information for assessment of potential impacts of the proposed action in relation to the above matters by PD.

This PD report has been prepared to provide the requested information in conjunction with the Santos referral to support a decision of the proposed action under the EPBC Act. This PD also provides information required by relevant sections of the Independent Expert Scientific Committee (IESC) "checklist" and responses to matters raise during their review and includes:

- Information contained in the original referral provided in March 2021 as Produced Water Releases – Fairview: Assessment of Matters of National Environmental Significance (MNES)[1]
- Additional information regarding potential impacts to:
  - groundwater and surface water resources and connectivity
  - surface water hydrology and water quality
  - groundwater dependent ecosystems (GDE) and
  - the white-throated snapping turtle, the Fitzroy River turtle habitat
  - risk from chemicals present in produced water and desalinated water released under the current GLNG Project and proposed GFD Project (as the proposed action) and
- Additional information and clarifications requested on the impacts of the action by the IESC on coal seam gas and large coal mining development review of the Draft PD and the strategies Santos propose to avoid, mitigate and offset identified impacts.

Details addressing the above matters are provided in this PD to demonstrate Santos' commitment to ensure potential impacts to MNES associated with the proposed action will be monitored, assessed and adequately managed.

Groundwater resources and groundwater / surface water connectivity

A detailed review and assessment of physical and chemical hydrogeology within the proposed action area confirmed the Evergreen Formation that is located directly between the proposed action and underlying Precipice Sandstone to be a low permeability aquitard isolating the Precipice Sandstone from the waterhole and the lower 11 km of the proposed action area drained by the Dawson River. The Precipice Sandstone provides baseflow water to the Dawson River upstream of the proposed action area.

Colluvial and alluvial sediments within and in the vicinity of the waterhole is sourced from surface water inflow from ephemeral drainage features within the waterhole catchment (including flows from the existing GLNG desalinated water release). There is no evidence from the hydrochemical data that there is any connectivity between the waterhole and groundwater in either the Evergreen Formation or Precipice Sandstone. Transient sediments within the Dawson River are considered a discontinuous aquifer with little or no effective storage that is in equilibrium with the Dawson River water and is regularly flushed during higher flows and flood events.

The proposed action is unlikely to result in a significant impact to groundwater resources as the low hydraulic conductivity of the Evergreen Formation aquitard prevents infiltration and storage of waterhole water, and the upward vertical gradient prevents entry of surface water into the Precipice Sandstone in outcropping areas. Assessment of the proposed action against applicable elements of the Significant Impact Guidelines (SIG) 1.3 (2013) for impact on water resources did not identify a likely direct or indirect impact of sufficient scale or intensity that results in a significant change to current or future groundwater water utility as summarised in Section 4.4.5.

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[1] As defined in the *Environmental Protection and Biodiversity Conservation Act, 1999* (Commonwealth)

Surface Water Resources

The hydrology and water quality within the drainage feature, waterhole and Dawson River were characterised using extensive existing monitoring data to assess the potential impact of the proposed action to hydrology, chemical and biological water quality. Review of potential hydrological impacts of current desalinated releases, and by inference the proposed action as a continuation of current releases found no significant impact to the existing receiving water hydrological regime.

The Dawson River within the proposed action area is a perennial (permanently flowing) river fed by groundwater from the Precipice Sandstone upstream. Flow depth and discharge ranges between 0.5 m and 20 ML/day during perennial baseflow conditions to greater than 9 m and 60,000 ML/day. 90% of flow is less than 40 ML/day.

Recorded water depth within the waterhole currently varies by +0.4 m to -0.5 m at its maximum and more typically ranges between ±0.2 m between desalinated water releases. Recorded water depth in the Dawson River during baseflow (low flow) does not increase more than 0.05 m (5 cm) at Yebna Crossing during desalinated water releases at both 13.5 ML/day and 18 ML/day release rate and occurs slowly over several days lagging behind the waterhole increase by at least a day. In contrast water depth increases in response to rainfall are rapid, occurring within one day. Water depth increases during flood flows are imperceptible in measured data and are calculated to be between 0.01 m and 0.04 m.

Review of measured and calculated impacts of current desalinated releases, and by inference the proposed action as a continuation of current releases, has found no significant impact to the existing water quality, sediment quality and biological indicators data at releases up to 18 ML/day.

Desalinated water is treated to protect the drinking water environmental value (EV) of the Dawson River as required under the State EA. The 95th percentile (used for screening water quality) of some parameters in the waterhole and Dawson River were above respective sub-regional water quality objectives (WQO), however these were pre-existing local conditions and not associated with the proposed action. Overall water quality in the waterhole has improved since the start of desalinated water releases in 2015 and will be maintained by the proposed action. No significant change to Dawson River water quality was identified when compared to upstream water quality data and by inference will not be impacted by the proposed action.

Biological indicators in the waterhole and Dawson River were found to be naturally variable in line with the local conditions but in the longer term did not display a decreasing trend in environmental quality. Waterhole biological diversity displays a decrease in the number of individuals (abundance) but an increase in the number of species (richness) and SIGNAL-2 scores indicating improving conditions.

Based on assessment of the proposed action against significant impact guidelines applicable for water resources, it was found that the proposed action is unlikely to directly or indirectly result in a significant change to the hydrological characteristics of a water resource or the water quality of a water resource that is of sufficient scale or intensity as to reduce the current or future utility for third party users, including environmental and other public benefit outcomes, or to create a material risk of such reduction in utility occurring. Assessment of the proposed action against applicable elements of the SIG 1.3 (2013) for impact on water resources did not identify a likely direct or indirect impact of sufficient scale or intensity that results in a significant change to current or future surface water utility as summarised in Section 5.5.7.

Groundwater Dependent Ecosystems

A desktop review and field assessment of groundwater dependent ecosystems (GDE) identified the presence and assumed presence of aquatic, terrestrial and subterranean GDEs in the proposed action area. An assessment of potential impacts utilised this data and long-term Receiving Environment Management Plan (REMP) data to assess potential impacts to GDE associated with the proposed action.

Terrestrial GDE (including Poplar Box Grassy Woodland on Alluvial Plains as a Threatened Ecological Community (TEC)) are identified to be less extensive around the waterhole than identified on State mapping, having been historically cleared in the early 2000's. The waterhole is not considered an aquatic GDE based on its reliance on surface water inflows from the surrounding catchment and is not maintained by groundwater from the underlying Evergreen Formation or the Precipice Sandstone.

Subterranean GDE are generally present in low diversity and abundances within the shallow Precipice Sandstone aquifer and are conservatively considered present in unconfined alluvial aquifers present within and adjacent to the Dawson River.

Review of REMP data indicate the proposed action will cause minimal changes to surface water, groundwater or sediment quality either in the waterhole or Dawson River. Similarly, changes to low flow hydrology within the Dawson River (i.e. water depth and velocity) will be minimal. Maintenance of water levels within the waterhole will be improved by the proposed action, through maintaining current pool habitat levels during dry periods.

Based on empirical REMP monitoring data (representative of the proposed releases), the proposed action will not significantly change physical geomorphology or Aquatic and Terrestrial GDE indicating no significant impact via flow rate, water volume or flow depth. Maintenance of water levels within the waterhole will be improved by maintaining current pool habitat levels through dry periods.

Assessment of the proposed action against significant impact guidelines applicable for water resources, found that it is unlikely to directly, or indirectly result in a significant change to the hydrological characteristics of a water resource or the water quality of a water resource, on which a GDE relies, that is of sufficient scale or intensity to reduce the current or future utility or to create a material risk of such reduction to the GDE. Assessment of the proposed action against the SIG 1.3 (2013) for impact on GDE did not identify a likely direct or indirect impact of sufficient scale or intensity that results in a significant change to GDE as summarised in Section 6.4.7.

White-throated snapping turtle and Fitzroy River Turtle

The Dawson River upstream and downstream of the proposed action area provides critical habitat for white-throated snapping turtle (critically endangered) and Fitzroy River turtle (vulnerable), noting that critical habitat for both species occurs throughout their full respective ranges within the Upper Dawson River catchment.

Assessment of habitat for the white-throated snapping turtle and Fitzroy River turtle identified the presence of suitable refuge, foraging, breeding and nesting habitat for both species within the Dawson River section of the proposed action area. The waterhole was not found to be critical habitat for species viability but does provide additional refuge opportunities.

The proposed action will cause minimal changes to water quality as the release has been designed to treat the water to a high specification using RO technology and manage the desalinated water release to achieve environmental outcomes. This includes key parameters such as dissolved oxygen and suspended solids that are important parameters for cloacal respiration by both MNES turtle species.

Changes to low flow hydrology (i.e. water level and velocity) will be minimal and do not increase risk of nest inundation during low flows or adversely impact foraging and residing habitat quality. Changes to high flow hydrology are indistinguishable from natural conditions.

The principal threat to both species of turtle is nest predation by introduced pigs, cats and foxes, with pig damage known along the banks of the Dawson River and trampling of nests by cattle.

Assessment of the proposed action against SIG 1.1 (2013) for MNES found it will not lead to a long-term decrease in the population size, reduction in the area of occupancy, fragment existing populations, adversely affect habitat critical to the survival, disrupt the breeding cycle, modify, destroy, remove, isolate or decrease the availability or quality of habitat. Therefore, the assessment found that the action will not result in a decline in numbers, to the extent that the species is likely to decline, result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat, introduce disease that may cause the species to decline, or interfere with the recovery of the Fitzroy River turtle or white throated snapping turtle as summarised in Section 7.2.5.

Chemical Risk Assessment

A chemical risk assessment was conducted to evaluate the potential risks and effects of chemicals used during coal seam gas operations (defined as drilling, hydraulic fracturing and water treatment) on MNES including the Fitzroy River turtle and white throated snapping turtle, environmental values and beneficial uses of water associated with the proposed action.

Water quality of desalinated water is required to meet the drinking water environmental value following treatment. Desalinated water meets the required State EA contaminant limits (for drinking water) and receiving environment water quality objectives. No unacceptable risk has been identified to the nesting, juvenile and adult life stages of MNES turtle species from the proposed action and is supported by current REMP data.

The aim of the chemical risk assessment was to also evaluate the potential risks and effects of chemicals and geogenic constituents within produced water after treatment to MNES that may be present within the Dawson River. The assessment included a desktop literature review relating to the MNES turtle's sensitivity to chemical exposure and considered a total of 146 chemicals in accordance with the *Fairview Water Release Scheme Chemical Risk Assessment Framework* (CRAF) (Santos, 2022). The CRAF categorised Tier 1 or Tier 2 chemicals as 'low risk', and Tier 3 as higher potential risk requiring a higher level of evaluation and assessment. Tier 4 or Tier 5 chemicals are categorised as 'high risk' and would require a higher level of site-specific assessment and likely require extensive management and mitigation controls to be in place.

For this assessment, 41 chemicals were categorised as Tier 1, 15 chemicals were classified as Tier 2, and 12 chemicals were categorised as Tier 3. No Tier 4 or Tier 5 chemicals were identified.

None of the chemicals were identified to be persistent, bioaccumulative and toxic (PBT). The chemical risk assessments completed for each chemical indicated negligible risks and effects of chemicals and geogenic constituents to MNES turtles when appropriate management and mitigation controls (including mixing in gathering networks, and produced water storages, residence times and water treatment processes) were in place.

Conclusion

The proposed action is for the release of up to 18 ML/day of desalinated water (cumulative total) to the Dawson River via a drainage feature, waterhole and outlet watercourse to the Dawson River. It is unlikely, however, that this maximum rate will be required due to prioritisation of other beneficial uses such as irrigation, except for under extreme wet weather events when these other beneficial uses become limited. Therefore, the 18 ML/day is considered inherently conservative.

There will be no increase in the existing approved maximum daily release rate of 18 ML/day (limited by the State EA) or total annual volume of 6,570 ML/year. GFD Project water will substitute GLNG Project water, and other water management and beneficial use options such as irrigation will remain in place.

The assessment of potential impacts associated with the proposed action has been conducted using long term empirical data collected from baseline and ongoing routine REMP monitoring data required under the State EA, additional survey, empirical calculations, and where applicable historical modelling. The assessment included review potential impacts to MNES via the Significant Impact Guidelines 1.1 (2013) and Significant Impact Guidelines 1.3 (2013) as specified in the DAWE Request for Information (RFI) together with applicable elements of the IESC checklist.

Based on review of empirical data, the proposed action, which represents no change from existing desalinated water release management practices, has not been found to have significant impact to MNES turtle habitat, physiological functionality or populations, water resources as a reduction in groundwater or surface water utility or associated ecological functionality to associated GDE.

Current monitoring and actions required under the State EA and REMP are considered to be suitable for the proposed action with the addition of refined turtle survey methods to better calculate MNES turtle numbers.

1.0 Introduction

AECOM Australia Pty Ltd (ABN 20 093 846 925 - AECOM) has been commissioned by Santos TOGA Pty Ltd (Santos), on behalf of the Santos GLNG joint venture participants (Santos TPY CSG, LLC; Santos TPY LLC; Santos Queensland LLC; Bronco Energy Pty Limited; Santos Toga Pty Ltd; PAPL (Upstream) Pty Limited, Total E&P Australia, Total E&P Australia II & KGLNG E&P Pty Ltd) (ABN 36 158 698 027 - Santos) to provide *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) approvals support for the Fairview Water Release Scheme (WRS) desalinated water releases from the Santos Gas Field Development (GFD) Project (the proposed action).

The proposed action is located within Petroleum Lease (PL) 232 of the Santos' Fairview Project Area (FPA), 50 kilometres (km) east of Injune, within the upper Dawson River sub-catchment of the Fitzroy River Basin, central southern Queensland (refer to Figure 1-1).

1.1 Background

Santos is an established producer of oil and gas in Australia, with existing approvals for the exploration and production of gas from coal seams in petroleum tenures making up the Arcadia, Fairview, Scotia and Roma Project Areas located within southern central Queensland.

In 2010, Santos received approval under the EPBC Act (EPBC 2008/4059) for the development of 2,650 coal seam gas (CSG) wells and associated infrastructure for the Gladstone Liquefied Natural Gas (GLNG) Project. The approval was provided prior to commencement of the "water trigger" under the *EPBC Amendment Act, 2013*.

In 2016, Santos received Commonwealth approval for the Santos GFD Project (EPBC 2012/6615) comprising the drilling of an additional 6,100 wells and installation of associated infrastructure over the same geographical area as the GLNG Project.

Authorised well counts for the original GLNG Project are close to being exhausted, meaning future development in the FPA will comprise production wells associated with the GFD Project.

The GLNG Project commenced in the FPA in 2011 with gas processing commencing in 2014. The natural gas is separated from the co-produced water, then compressed and fed into the 420 km gas transmissions pipeline to Gladstone.

Produced water is aggregated and pumped to water management and treatment facilities. Water management then includes a combination of methods prioritising beneficial use such as drip irrigation of forested land, pivot irrigation for fodder crops, construction and operational activities such as dust control and compaction with excess treated (desalinated via the existing reverse osmosis plant (ROP)) water stored in a desalinated water balance (DWB) pond at Hub Compression Station 04 (HCS04) prior to release to the ephemeral drainage feature as described in Section 2.0.

The release of desalinated water from HCS04 to the ephemeral drainage feature[2] has occurred since 2015. From the discharge point in the ephemeral drainage feature the released desalinated water flows down to a waterhole and subsequently out via an ephemeral watercourse[3] to the Dawson River.

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[2] As mapped in Queensland Globe and defined in the Queensland *Water Act, 2000* – referred to in previous documents as "the gully" or "tributary gully"
[3] As mapped in Queensland Globe and defined in the Queensland *Water Act, 2000* – referred to in previous reports as "oxbow" or wetland.

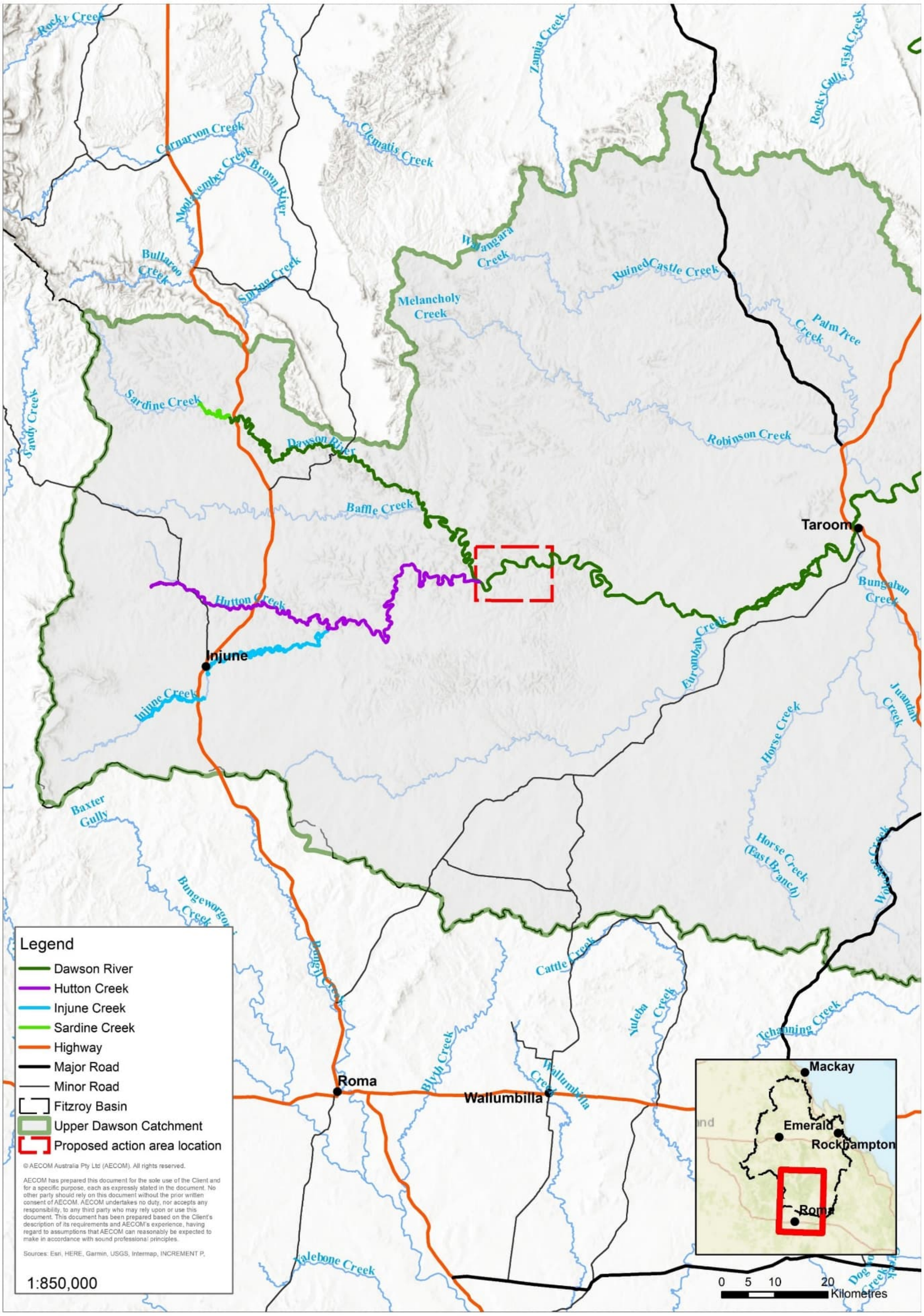

Figure 1-1 Proposed action location

It is proposed that water from the GLNG Project and GFD Project share project infrastructure, including water management infrastructure. The discharge of treated (desalinated) water is authorised by the State Environmental Authority (State EA) until 23 July 2026. Should the proposed action be approved under the EPBC Act, Santos proposes to lodge an EA amendment to facilitate ongoing treated water discharges for the combined GLNG Project and GFD Project until their respective end dates.

The proposed action is to gain Commonwealth approval for desalinated water discharges to the Dawson River via the waterhole for water associated with the GFD Project using the existing water management infrastructure based at HCS04. Approval of the proposed action described in Section 1.2 will allow an uninterrupted transition of gas supply to market.

1.2 Proposed action

1.2.1 Amendment to the proposed action

In the original EPBC referral submitted in March 2021, Santos was seeking Commonwealth approval for both a desalinated and event-based releases of co-produced water. The original Preliminary Documentation (PD) Revision A (Rev. A) included impact assessment for both desalinated releases and event-based releases.

Santos subsequently made the decision that event-based releases are no longer required as a contingency measure for water management and applied to the Commonwealth Government to vary the action. No event-based release infrastructure is in place and the event-based release is not incorporated into any current or future water management plan.

1.2.2 Revised proposed action

Santos is seeking Commonwealth approval to release up to 18 ML/day of desalinated produced water to the Dawson River via a drainage feature, waterhole and outlet watercourse to the Dawson River.

There will be no increase in the existing approved maximum daily release rate (18 ML/day) or total annual volume of 6,570 ML/year (limited by the State EA). GFD Project water will substitute GLNG Project water, and other water management and beneficial use options such as irrigation will remain in place.

Water management and treatment prior to the proposed action will use existing water management and water treatment infrastructure at HCS04, including the ROP, water storage ponds and desalinated water release pipe from HCS04 to the drainage feature.

The proposed action area is limited to the area defined by the desalinated water release pipe point (approximately 5 km east of the HCS04 ROP) to an ephemeral drainage feature, to a waterhole (oxbow lake), and then via a watercourse to the Dawson River, and the Dawson River to the downstream monitoring point S4 located at Yebna Crossing[4] (see Figure 1-2).

A detailed description of the current water management strategy and the proposed action is presented in Section 2.0.

1.3 Approval pathway / status

1.3.1 EPBC referral

The release of produced water to the Dawson River is not authorised by the GFD Project EPBC approval 2012/6615 (condition 2A). In March 2021, Santos submitted a referral to the Minister for the Environment for a decision on whether assessment and approval of the original proposed action (desalinated and event-based releases[5] for the GFD Project) was required under the EPBC Act (EPBC 2021/8914).

On 7 July 2021, the delegate of the Minister for the Environment determined the proposed action was likely to have a significant impact on the following matters protected under Part 3 of the EPBC Act:

[4] The proposed action area defines the general limits of the proposed action. Consideration of potential impacts extends beyond the proposed action area.
[5] No longer part of the proposed action.

- listed threatened species and communities (sections 18 and 18A), and
- a water resource, in relation to coal seam gas development and large coal mining development (sections 24D and 24E).

With this determination, the Department of Climate Change, Energy, Environment and Water (DCCEEW), then the Department of Agriculture, Water and the Environment (DAWE), issued a request for additional information for assessment by Preliminary Documentation, provided as Appendix A for reference, and referred herein as the 'DAWE RFI'. This included the provision of information for assessment by the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC).

1.3.2 Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC).

The IESC is a statutory body under the EPBC Act. The IESC's key function is to provide scientific advice to the Commonwealth Environment Minister and relevant State ministers in relation to CSG or large coal mining development proposals that are likely to have a significant impact on water resources.

To allow the IESC to provide robust scientific advice to government regulators on water-related impacts of CSG, an information guideline (IESC 2018a) has been developed outlining the information considered necessary for the IESC to undertake the relevant assessment.

The IESC Information guidelines (IESC, 2018) have been used in this assessment. It is recognised that elements of the IESC information guidelines are either not applicable or only partially applicable as those activities do not form part of the proposed action.

1.3.3 Preliminary documentation and IESC submission – Revision A

On 01 June 2022, the PD Rev. A report was submitted to DCCEEW for adequacy review. The PD Rev. A report and appendices presented information requested by the DAWE RFI, and together with the March 2021 EPBC referral formed the PD submission.

The PD Rev. A submission assessed potential impacts of both desalinated and event-based releases, and included information for assessment by the IESC, including a copy of the IESC checklist indicating the sections of the report where applicable information was presented.

1.3.4 Preliminary documentation adequacy review

On 04 August 2022, the DCCEEW and IESC responded to the PD Rev. A submission with adequacy comments to be addressed by the proponent. These are presented in Appendix B-2 for DCCEEW comments and Appendix C-2 for IESC comments. General DCCEEW comments included:

- Provision of the list of figures and tables in the PD below the table of contents.
- Provision of the current State EA approval as its own appendix item and confirm the duration of treated water release, as the State EA provided with the PD Rev. A states "the release of contaminants to waters from ROP2 in accordance with condition (B15) must cease on or before 23 July 2026".
- The IESC has identified multiple areas of concern regarding the proposed action and the level of information provided. As there may be the potential for the proposed action to result in a significant residual impact to listed threatened species the department considers the impact assessments and requirements for offsets be reviewed and updated as required.
- Avoidance, mitigation and management measures should be expanded upon based on the consideration of the IESC advice. This section of the PD should also summarise avoidance, mitigation and management measures discussed in the Receiving Environmental Management Plan (REMP) or State EA conditions that Santos is required to comply with.
- Due to the size of the appendices, the department requests that appendix items be provided as individual documents with the updated PD, alternatively the appendices can be provided as a single document with a table of contents which is linked to the individual appendix items.

Detailed IESC adequacy review comments are included in Appendix C-2 together with a table summarising the responses.

This PD Rev. B has been revised and updated to:

- support the application for desalinated water releases only, including updated risk assessment
- provide the information requested in the initial DAWE RFI (as relevant to desalinated releases)
- respond to the DCCEEW and IESC comments received on 04 August 2022
- provide an updated IESC checklist.

Assessment of the proposed action via PD has been completed utilising a large data set of empirical data predominantly gathered from between 2013 and 2022, a range of literature reviews and research drawing on current understanding of MNES, conceptualisation(s) to assist in informing the assessment, modelling and empirical calculations where current data is not available together with third party data to provide regional context where applicable. Specific details of data sources used for assessment of the proposed action are provided in respective sections.

1.4 State Environmental Authority

The State EA provides the conditioned authority for the GLNG and GFD projects. The State EA currently permits the release of desalinated water from HSC04 until the 23 July 2026 (based on the timeframe proposed within the Dawson River Release Scheme EA Amendment Application [Santos, 2012]).

Santos proposes to submit an application to extend desalinated water releases for the GLNG and GFD Projects from HCS04 (ROP2) well in advance of the July 2026 expiry date, pending Commonwealth approval of the proposed action.

1.5 Structure of the report appendices:

Based on the refinement of the proposed action described in the sections above, this PD includes the following appendices:

Table 1-1 Preliminary documentation appendices

Appendix	Title	Change from Rev A
Appendix A	DAWE RFI	NA
Appendix B-1	DAWE Information Request Cross Reference Table	*Updated to cross-reference Rev B amended layout and action*
Appendix B-2:	DCCEEW matters to be addressed (4 August 2022):	*New – responses and cross-reference table*
Appendix C:	C-1 IESC checklist C-2 Proponent responses to IESC comments issued 04 August 2022	*Updated - to cross-reference amended report layout and revised action of desalinated water releases only* New
Appendix D:	State EA EPPG00928713	*Updated - as revised 03 November 2022; previous issue dated September 2020*
Appendix E	E-1 Water quality summary statistics – Waterhole E-2 Water quality summary statistics – Waterhole and Dawson River	*Updated - Water quality statistics updated to include REMP data collected between July 2021 and June 2022*

Appendix	Title	Change from Rev A
	E-3 Sediment quality summary statistics – Waterhole and Dawson River	*New – sediment quality data tables*
Appendix F	Receiving Environment Monitoring Program (REMP) reports	*2021 REMP Annual Report replaces 2021-Interim-REMP-post-wet report. 2022 Interim report*
Appendix G*	BOOBOOK Groundwater Dependent Ecosystems (GDE) Report	*Unchanged – coversheet added indicating removal of event-based releases*
Appendix H*	BOOBOOK Turtles Report	*Unchanged – coversheet added indicating removal of event-based releases*
Appendix I	I-1 – Chemical Risk Assessment Framework (CRAF) Fairview Water Release Scheme I-2 – Tier 3 Chemical Risk Assessment - Tables	*Updated*
Appendix J	Proposed REMP Program	*Updated – additional monitoring proposed in response to IESC comments, and event-based discharge monitoring removed.*

* Technical report appendices G and H have not been revised to remove references to, and assessment of, event-based releases. An addendum coversheet has been inserted to these technical reports, to advise that assessment is to consider information that informs impact assessment of desalinated releases (the current water management strategy) only.

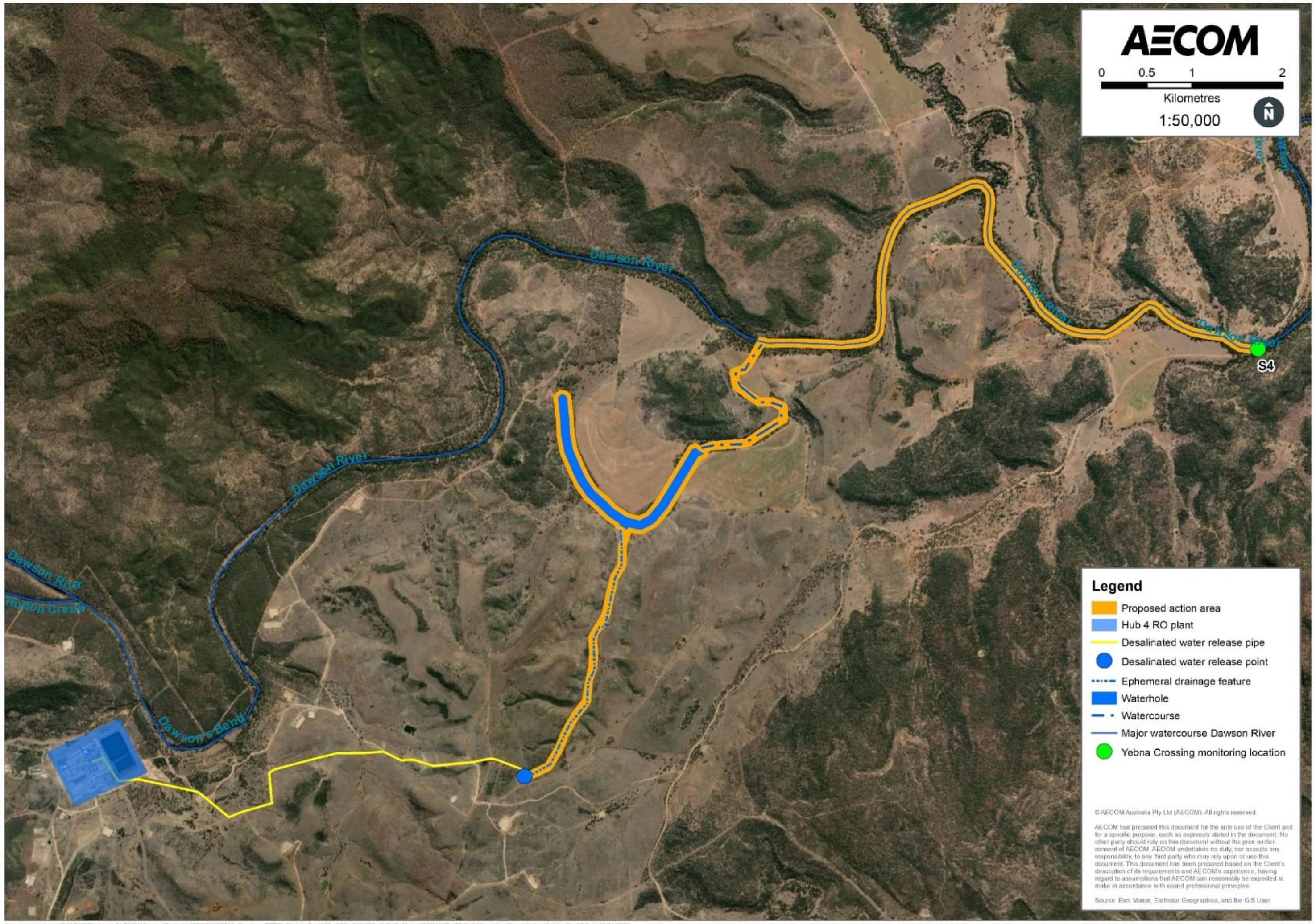

Figure 1-2 Proposed action area, release locations and receiving environment

1.6 Economic and social matters

1.6.1 Economic and social impacts

A Social Impact Assessment (SIA), a thorough analysis of the economic and social impacts, was undertaken prior to the commencement of the GLNG Project. From the data collected during this process a Social Impact Management Plan was developed and submitted to the Queensland Coordinator General for approval. In May 2012 the Social Impact Management Plan was approved and adopted by Santos. It provides strategic direction for activities undertaken by Santos including the GFD Project and all subsequent approvals within Arcadia, Fairview, Scotia, and Roma Project Areas within southern central Queensland. The Social Impact Management Plan will cover the proposed action.

The Social Impact Management Plan assesses various key topics and identifies potential impacts and mitigations accordingly. Impacts, both positive and negative are categorised into the following interest areas:

- Water and environment
- Community safety
- Social infrastructure
- Local industry participation and training, and
- Aboriginal engagement and participation.

For each of the topics, the following aspects have been considered:

- Understanding the issues and opportunities
- Predicting the likely impacts/contributions
- Developing mitigation/enhancement strategies, and
- Applying adaptive management practices.

Given the relatively remote location of the proposed action area, the continued release of GFD Project water within the desalinated water releases from the existing infrastructure, and that no additional employees will be required for the operational phase of the project (operation of the infrastructure will be absorbed by the current field staff), the social impact of Santos' activities will be very minimal and manageable.

1.6.2 Public consultation

Stakeholder participation and consultation is essential to build mutual respect, trust and acceptance of Santos' activities. Santos conducts extensive community engagement across its operational areas. The closest communities in proximity to the FPA are Taroom and Injune, approximately a 1-hour drive either east or west from the proposed action area. Engagement activities include:

- Regular engagement with the mayors, councillors, CEOs and staff of Banana Shire Council and Maranoa Regional Council
- Hosting of community barbeques, at least twice annually, to provide an opportunity for community members to informally meet and discuss current and proposed activities and raise any issues of concern
- Sponsorship and attendance at community events in both Taroom and Injune, by dedicated land access and community staff to ensure that members of the community can speak directly with company representatives including regional shows, camp drafts, art shows and School Science, Technology, Engineering and Maths (STEM) programs
- Regular community newsletters disseminated electronically to all interested stakeholders, and
- Maintenance of a company website, free call 1800 community enquiries line, email address and dedicated staffed shopfront in Roma.

Engagement in the region has been well received and has helped foster open communication with landholders and the wider community.

1.6.3 Indigenous engagement

Santos aspires to partner with, and be trusted by, Indigenous people within local communities and strives to achieve the following targets:

- Industry best-practice recruitment and development programs for meaningful career opportunities
- Leader in community engagement and cultural heritage management, and
- Support Indigenous businesses through our supply chain.

Santos has mature relationships with both Iman #4 and Wardingarri. Wardingarri, formerly Iman People #2, (QUD6162/1998) have full native title rights following a positive determination in 2016. Iman People #4 have a registered claim (QUD413/2017) and are entitled to some native title rights. As part of ongoing engagement, a specific briefing on the Proposed Action was provided on 21 October 2022 in Brisbane. As an outcome of the meeting actions were assigned with a commitment for further engagement in 2023.

Whilst known areas of cultural significance exist within the vicinity of the proposed action, Santos has negotiated and executed Cultural Heritage Agreements; cultural heritage management plan (CHMP) and cultural heritage management agreement (CHMA) with the cultural heritage bodies for the entire area of the GLNG and GFD Projects for the purpose of managing cultural heritage for the life cycle of project activities. These agreements have varying commencement dates and largely follow the same model based on working in partnership with Indigenous parties to ensure best practice management is applied.

The CHMP is fundamentally based on the avoidance principle and is defined by the relevant Indigenous party who self-manage this aspect, providing input and advice to Santos. The parties are engaged and informed for each stage of the project. Engagement will continue through the course of the assessment period and the duration of the activity as is required and/or agreed. Cultural Heritage Agreements are confidential documents, containing culturally sensitive information. Further information regarding Cultural Heritage Agreements can be provided to DCCEEW upon request.

Cultural awareness sessions are also delivered by the cultural heritage parties to contractors and Santos' staff who undertake any activity capable of creating ground disturbance. Online cultural heritage induction modules are also available to Santos' staff and contractors through training portals. During activities associated with the proposed action the find, stop, notify, and manage procedure will be implemented for any suspected or actual unexpected finds of cultural significance.

1.6.4 Projected economic costs and benefits

The USD $18.5B Santos GLNG Project was sanctioned in January 2011. It is a joint venture partnership between Santos TPY CSG, LLC; Santos TPY LLC; Santos Queensland LLC; Bronco Energy Pty Limited; Santos Toga Pty Ltd; PAPL (Upstream) Pty Limited, Total E&P Australia, Total E&P Australia II & KGLNG E&P Pty Ltd.

The Santos GLNG Project has already contributed almost $300 million in royalties to the Queensland State Government and will continue to deliver these benefits for years to come, providing much needed revenue to fund vital infrastructure, health and education initiatives across the State. The GFD Project is anticipated to contribute additional royalties to the Queensland State Government during its operational phase.

Since the GLNG Project commencement in 2011, Santos has directly contributed over $200 million in social investment to mitigate any of the social impacts that the GLNG Project may cause, including road upgrade, LifeFlight aeromedical service, upgrades of airports and medical facilities, housing initiatives, grants for community groups and organisations, delivery of STEM programs, industry open days with students from across the region including Taroom and Injune State Schools and access to Santos health and recreation facilities. These initiatives together with ongoing initiatives during the GFD Project will continue to support the communities where Santos operates and promote a vibrant and sustainable future for the regions.

Full, fair and reasonable opportunities will be provided to local and indigenous individuals and businesses within the region. The GLNG Project supported approximately 6,000 roles during construction and approximately 1,000 direct and indirect roles during operations. The proposed action specifically will provide minimal additional employment opportunities as the oversight and management of GFD water management will be absorbed by the current workforce, however, it supports these roles.

1.7 Proponents environmental record

Under Commonwealth, State or Territory law for protection of the environment and/or conservation and sustainable use of resources, Santos (including subsidiary companies) has recorded the following proceedings:

- July 2018, Santos received a $68,000 fine from the Queensland Department of Environment and Science for the unauthorised release of hydrocarbons to land, and
- June 2013, Santos NSW (Eastern) Pty Ltd pleaded guilty in the NSW Land and Environment Court for proceedings relating to breaches of the NSW Petroleum (Onshore) Act 1991 for past reporting failures in the Pilliga Forest. Santos NSW (Eastern) Pty Ltd was fined $52,500.

2.0 Current water management and the proposed action

Chapter summary

Produced water management for the Fairview Water Release Scheme is based on the Queensland Coal Seam Gas Water Management Policy (2012) and prioritises beneficial reuse of produced water where feasible.

The proposed action supports a continuation of existing water management practices used for the GLNG Project (which have occurred since 2015) including discharge of treated water (desalinated via reverse osmosis) to the Dawson River of no more than 6,570 ML/Year (18 ML/day) as permitted subject to limits and conditions under the current State EA for the GLNG and GFD projects. No new infrastructure is required for the proposed action and no increase in volume of maximum discharge rates are required.

Based on 2021 data, 70% of produced water is beneficially used for irrigation or operational use, with the remaining 30% released to the Dawson River or lost through evaporation or contained within storages, including brine storage volumes. Specifically, based on this 2021 data, 60% was used for drip, and pivot irrigation schemes, 10% for operational use, 5% lost to evaporation, 5% contained in storages (awaiting treatment and use or contained within brine) and the remaining 20% discharged as treated desalinated water to the waterhole and subsequently the Dawson River.

Discharged water is required under the State EA to be treated to levels that protect the receiving water environmental values as well as drinking water values.

2.1 Proposed action area

The proposed action is located within Santos' existing FPA, situated in the lower reaches of the Upper Dawson River sub-catchment as indicated in Figure 1-1. The Upper Dawson River sub-catchment is situated within the Fitzroy River Basin, which is the second largest externally drained basin in Australia and the largest on the east coast. At almost 150,000 km^2, the Fitzroy River basin contains several significant tributaries, including the Nogoa, Comet, Mackenzie and Dawson Rivers. The Fitzroy River eventually discharges into the Coral Sea east of Rockhampton.

The proposed action area comprises the area between the existing GLNG Project desalinated water release point, the ephemeral drainage feature that in turn flows to a waterhole and subsequently via a watercourse to the Dawson River, and the downstream monitoring location (S4, located at Yebna Crossing) on the Dawson River **(**Figure 1-2). The width of the proposed action area includes a 50 metre (m) buffer from the centre line of the drainage feature, waterhole shoreline, watercourse centreline and high flow channel of the Dawson River.

Based on review of the Queensland Globe[6] land use layer, adjacent land uses to the proposed action area are dominated by grazing, native vegetation, cropping and production forestry.

Downstream of the proposed action area the Dawson River supplies water for town water, industrial and irrigation under the Dawson Valley Water Supply Scheme operated by Theodore Water. The scheme collects water at six weirs; Theodore, Orange Creek, Moura, Glebe, Neville Hewitt and Gyranda Weirs and contains the Theodore and Gibber Gunyah channel systems[7].

Sunwater manages the weirs located on the Dawson River. The closest weir to the proposed action is Glebe weir located 56 km downstream of Taroom and 156 km downstream of Yebna crossing, the lower point of the proposed action area. The Glebe weir receives water from the Dawson River (including the Santos GLNG Project desalinated water releases) and the Glebe Beneficial Use Scheme (GBUS) consisting of coal seam gas water treated at the Northern Water Treatment Plant for use by irrigators[6]. Abstraction (pumping/removal) of water from the Dawson River for irrigation of crops is also completed between the proposed action area and Taroom (refer to Section 3.3).

[6] https://qldglobe.information.qld.gov.au/
[7] https://www.sunwater.com.au/schemes/dawson-valley/#:~:text=The%20Dawson%20Valley%20Scheme%20consists,as%20urban%20and%20industrial%20users.

2.2 Produced water management

The proposed action is the release of desalinated water from existing infrastructure only. The following sections include contextual detail on the existing water management and treatment process, beneficial uses of water, HCS04 infrastructure, relevant to the management of water releases that are proposed to be used for the proposed action. Figure 2-1 provides a conceptual diagram of the current produced water management process.

Water from gas wells (known as produced water) will be collected from well pads via gathering lines and transferred to existing produced water management ponds and water management and treatment facilities. Stored produced water will then be used for beneficial uses such as construction operations, drilling and well completions, or treated and/or blended for irrigation, or released via pipeline to the head of the ephemeral drainage feature and subsequently to the waterhole and Dawson River.

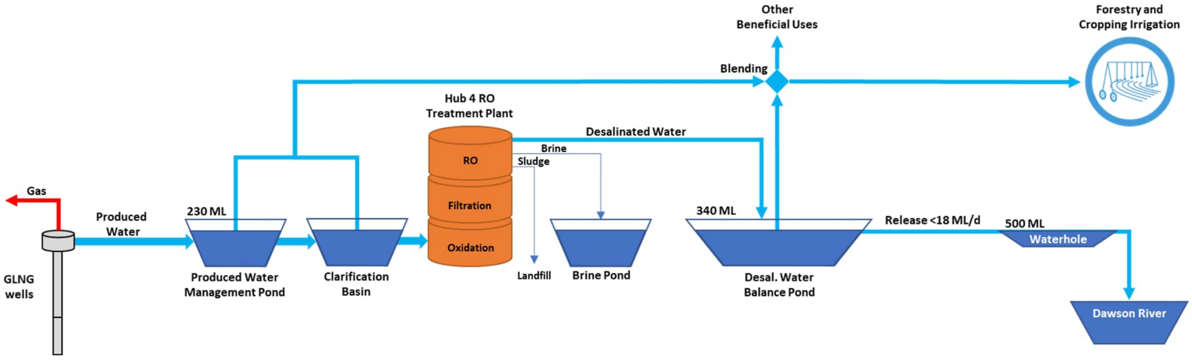

Figure 2-1 Conceptualisation of current water management

2.2.1 Produced water management and treatment process

Produced water from the GLNG Project is managed via the process summarised in Section 2.2.1.1 to Section 2.2.1.4**.**

2.2.1.1 Produced water collection

Produced water from wells is collected via gathering lines and transported to a produced water management pond located at HCS04 where the water treatment and ROP is located (referred to as HCS04 ROP). Produced water is mixed either in gathering lines during transit or ponds at the HCS04 as shown in Figure 2-1.

2.2.1.2 Produced water management pond

The produced water management pond at HCS04 has a 230 ML total capacity and is sized for 10 days storage with a 200 ML maximum operating volume at peak production rates. The additional 30 ML is freeboard capacity designed to contain one wet season's worth of rain that falls directly on to the pond.

2.2.1.3 Water treatment

The water treatment at HCS04 is a ROP designed to produce high quality treated water suitable for irrigation or release to the Dawson River (and subsequent use for irrigation and town supply downstream). The plant utilises a combination of physical and chemical treatment processes including coagulation/clarification, oxidation, micro-filtration, high-recovery reverse osmosis, and finally adjustment of sodium adsorption ratio (SAR). The treated water produced by RO is referred to as permeate or desalinated water.

The by-products of the treatment process include a concentrated salty water stream ("brine") and a concentrated solids stream ("sludge"). For every 1,000 parts of water processed, approximately 89% is converted to desalinated water, approx. 10% is brine and about 1% sludge. The brine is sent to storage ponds, while the solids are collected by trucks and sent to landfill.

Coagulation/Clarification

The first step of the treatment process involves the removal of large particles and dissolved organic material. This is done through coagulation and clarification. Coagulation involves adding small amounts of chemical coagulants to promote the agglomeration of small suspended matter into larger particles. Clarification is the process of allowing these coagulated particles to settle to the bottom of a specially engineered basin. Treated water following coagulation and clarification overflows the top of the clarification basin and is collected for further treatment within HCS04.

Oxidation

The clarified water from the clarification basin is sent through an oxidation step to separate out any dissolved inorganics (such as iron, manganese, and arsenic). Through oxidation, these are converted into filterable forms. Oxidation is done using chlorine in the form of sodium-hypochlorite. The oxidation step will also remove any remaining organics which were not removed through the clarification step.

Filtration

Filtration is carried out using multi-media filters. These contain three specific media layers:

- anthracite (a coarse pre-filter media)
- sand (for fine filtration)
- garnet (as a base layer).

The filtration step is used to remove the solids created during the oxidation step as well as remove any fine particulate that are carried over from the clarification step.

Reverse osmosis

Multiple stages of RO units are used to remove dissolved salts (also known as salinity, total dissolved solids (TDS)). RO is a common and established water treatment process used to treat seawater and wastewater containing salts and chemicals to potable standards from a household (under-sink) scale to commercial scale as a component for treating wastewater from sewage treatment plants to potable water standards.

The concentration of dissolved salts is often quantified through measurement of Electrical Conductivity (EC). The RO units use membranes with extremely small pore sizes that allow water molecules to pass through but limit the passage of salts, resulting in desalinated water with very low salinity. Because of the robust upstream pre-treatment processes a desalinated water recovery of approximately 89% is achieved. Organic chemical removal rate ranges between 95% and 99% depending on chemical type and structure. Specific chemical removal rates in the RO and additional treatment stages are provided in Section 8.3.3 and Appendix I-1 and Appendix I-2.

The concentrated salt solution (brine) is collected and transferred to the brine collection system.

Adjustment of SAR

Calcium chloride dehydrate is added to the desalinated water to reach a target Ca-Cl concentration of 5–18 mg/L and a range of SAR of between 2 and 20.

Waste return system

Many of the above systems require regular flushing operations to maintain their performance:

- the filtration system requires backwashing to remove accumulated particles
- the softening process requires a non-chemical flush after resin regeneration.

The wash water used in the above processes is collected and sent to the waste return tank where it is collected and recycled to the head of the plant for re-treatment. This recycling improves the overall efficiency of the treatment plant.

Regeneration waste system

The RO process requires regular chemical cleaning of the units to remove accumulated unwanted materials that collect within the membranes.

The chemical wastewater from these processes is collected and directed to the Regeneration Waste Tank. From there it is transferred to the brine collection system for subsequent off-site disposal to landfill with brine solids.

2.2.1.4 Desalinated water management

Desalinated water is stored at HCS04 in a Desalinated Water Balance (DWB) pond with a 340 ML maximum design capacity that is sized for 15 days storage at peak production of the RO plant. The DWB pond has a total volume of 386 ML with the 46 ML freeboard designed to accommodate 100% wet season rainfall.

In line with the Queensland Coal Seam Gas Water Management Policy[8] (2012) prioritised water management of treated water in the desalinated water pond is via beneficial re-use for forestry and crop irrigation or in construction (dust suppression) and operations. Based on climatic conditions, desalinated water will be released to the Dawson River via existing infrastructure under the proposed action.

Peak production of the HCS04 ROP is not regularly achieved due to the volume / rate of produced water production and diversion of water to beneficial uses as discussed in Section 2.2.2**.** This reduces overall treated water accumulation in the DWB pond and subsequently reduces the volume and frequency of desalinated water releases.

Water beneficially used for irrigation, and operational use (Figure 2-2) minimises the volume of desalinated water released to the Dawson River. The water management operation of the DWB pond is designed to maximise beneficial water use for irrigation and reduce reliance on desalinated water releases to the Dawson River, in consideration of climatic conditions.

The trigger for pumping down of the DWB pond will be generally started once the net balance of water in the DWB pond reaches 90 to 95% capacity. Once pumping is triggered, desalinated water is:

- transferred via a 5.3 km pipeline to a release point located at the upper limit of an ephemeral drainage feature and released to a fenced, rock-lined outlet via a diffuser
- the released desalinated water flows for 2.9 km down topographical gradient of an ephemeral drainage feature before discharging into a waterhole. The ephemeral drainage feature has been partially rock armoured in selected areas of identified higher potential erosion for protection from scouring; and
- will enter the waterhole, which is a semi-permanent water body estimated to have a volume of approximately 500 ML. The waterhole naturally discharges via a 2.2 km watercourse discharging into the Dawson River midway between “Dawson’s Bend” and “Yebna Crossing” (refer to Figure 1-2)

Once the DWB pond levels fall to approximately 50% capacity pumping will generally stop and desalinated water slowly accumulates from the HCS04 ROP until levels reach 90 to 95% (unless the water is diverted to irrigation) and the release process is repeated.

2.2.2 Beneficial uses of produced treated water

Under the existing water management strategy, beneficial use of produced water is prioritised via pivot irrigation to agricultural land (in the vicinity of the treatment plant) and to drip irrigation to managed forestry. Santos operates extensive pivot and drip irrigation schemes on the most suitable land areas within the FPA.

As an example, and based on 2021 data under the water management strategy produced water distribution includes:

- 60% is used irrigation either as drip irrigation to forested area and/or pivot irrigation

[8] https://environment.des.qld.gov.au/management/activities/non-mining/water/csg-water

- 10% is used for operational activities such as dust suppression, construction, drilling etc)
- 5% is lost to net evaporation
- 5% is stored water including brine and
- 20% is released as desalinated water to the Dawson River.

This is summarised graphically in Figure 2-2.

Based on the 2021 data in Figure 2-2 current water management for the Fairview WRS is in line with Priority 1 and Priority 2 of the Coal Seam Water Management Policy (2012) using both produced water and treated water for other beneficial uses and only after those beneficial uses are completed discharging the treated component of water at a quality that minimises and mitigates impacts on environmental values (EV).

For discharged desalinated water remaining after all other beneficial uses are used the EV to be protected under the State EA is defined in Schedule B as being for drinking water as referenced in B19 and B20.

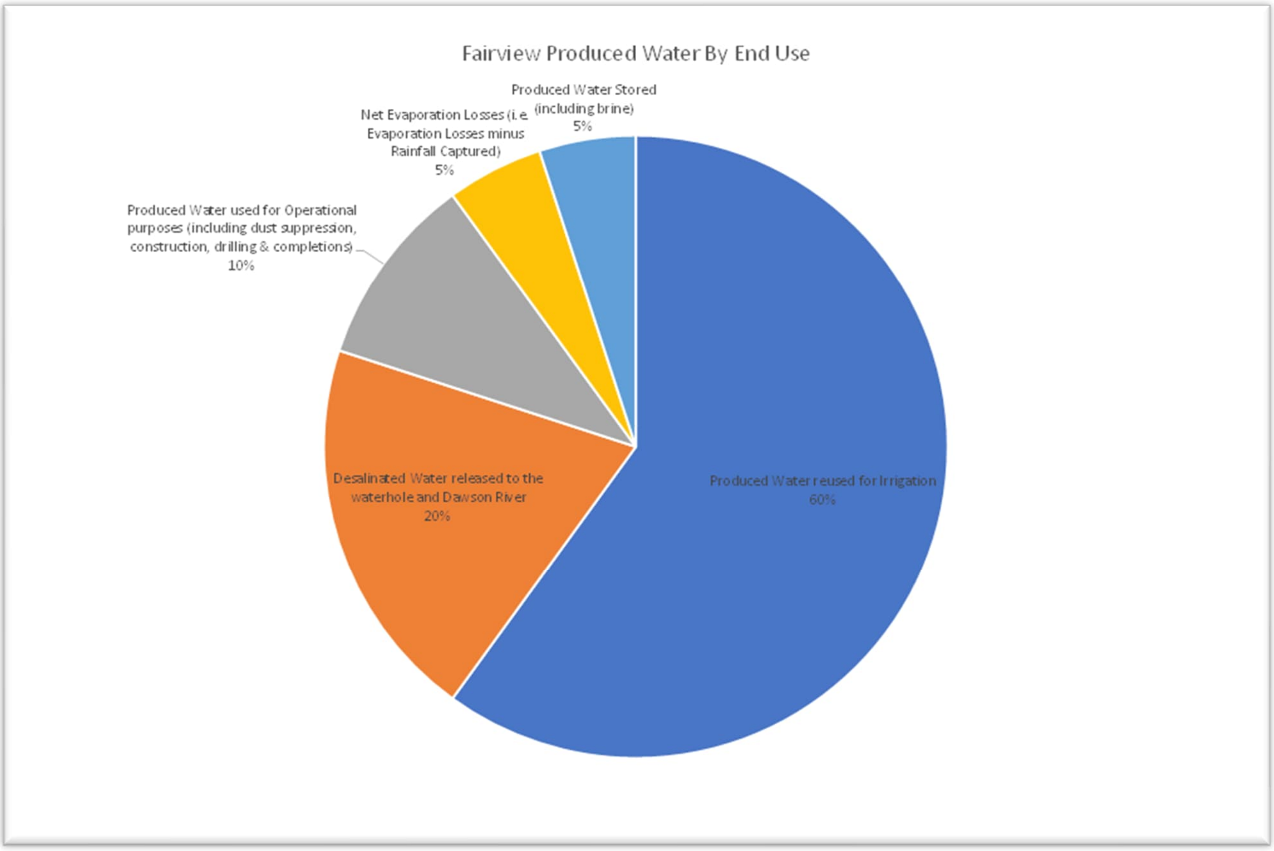

Figure 2-2 Fairview WRS produced water distribution by end use for 2021

2.2.3 Desalinated water releases

The frequency and duration of each desalinated water release is variable in both duration, rate and volume as indicated in Figure 2-3. There are 5 x 4.2 ML/day pumps available at the HCS04 ROP, however the State EA limits the release rate to 18ML/day. The same pumps are used for multiple purposes in the overall water management cycle at the HCS04 ROP such as transfer of water to irrigation areas.

The existing desalinated water release point is presented in Figure 1-2. This location was chosen in 2013 based on factors such as proximity to existing infrastructure, land access, cultural and heritage constraints and distance to environmental receptors, together with physicochemical factors that allowed the released desalinated water to equilibrate to ambient receiving environment conditions of temperature and dissolved oxygen (DO).

Based on the water management strategy indicated above, Table 2-1 provides a summary of desalinated water released between July 2015 and December 2021 for the existing GLNG Project.

Figure 2-3 provides actual GLNG desalinated water release data between January 2015 to June 2022 period. The decrease in release frequency over the 2021 and 2022 period is due to a revised water management regime and due to the construction of additional irrigation areas. The 2021 date would be considered representative of the desalinated water release regime for the proposed action, subject to climatic conditions and gas development.

Table 2-1 Desalinated water release summary 2015 to 2021

Year	Total No. of Release Days in Year	Release Rate (ML/day)	Annual Release (ML)	State EA Approved Annual Release (ML)
2015	22	13.5	262.7	6,570[a]
2016	87	13.5 to 18 ML/day	1,106.1	
2017	97	13.5 to 18 ML/day	1,248.9	
2018	111	13.5	1,433.6	
2019	143	13.5	1,874.0	
2020	156	13.5	2,077.5	
2021	95[b]	13.5	1,223.8	
Average [c]	**114.8**	**-**	**1,494.0**	

a – State EA approved annual release based on 18 ML/day x 365 days

b - Reduced 2021 release days is due to revised water management procedures directing more water to beneficial reuse via irrigation.

C – Excluding 2015 as discharges commenced mid-way through the year

Infrastructure associated with the GLNG Project desalinated water release is built and operational. The same desalinated water release infrastructure will be used for the proposed action. No additional infrastructure is required for the proposed action.

2.2.4 Management of water releases

The State EA for water releases imposes water quality limits and requires monitoring of the desalinated release water and receiving environment to ensure that environmental values are being protected and not adversely impacted by authorised releases. Condition B35 of the State EA required the development and implementation of a REMP. Conditions B36 and B38 require the REMP to describe and monitor potentially affected receiving waters and applicable environmental values: hydrology, physicochemical properties, drinking water suitability, aquatic ecosystems and geomorphological features including bank stability and erosion. Monitoring completed under the State EA and REMP is summarised in Section 9.0. The full REMP is attached as Appendix J.

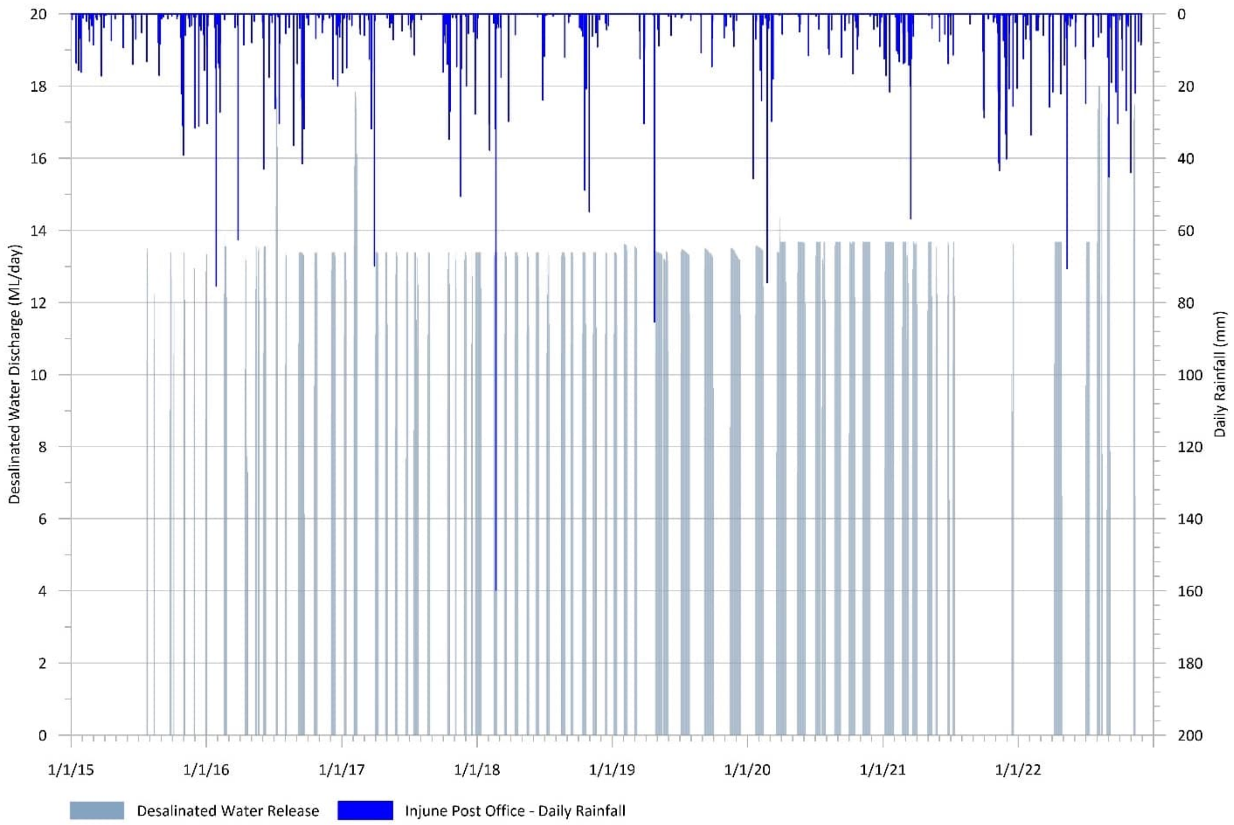

Figure 2-3 Desalinated water release data from the HCS04 ROP between 2015 and 2022 (source: Santos)

2.3 Proposed action description

Santos is seeking Commonwealth approval to release up to 18 ML/day of desalinated produced water to the Dawson River via a drainage feature, waterhole and outlet watercourse to the Dawson River.

There will be no increase in the existing approved maximum daily release rate (18 ML/day) or total annual volume of 6,570 ML/year (limited by the State EA). GFD Project water will substitute GLNG Project water, and other water management and beneficial use options such as irrigation will remain in place.

Water management and treatment prior to the proposed action will use existing water management and water treatment infrastructure at HCS04, including the ROP, water storage ponds and desalinated water release pipe from HCS04 to the drainage feature as described in Section 2.2.1.

Figure 2-4 presents the conceptualisation of the proposed action. The only difference from Figure 2-1 in the conceptualisation prior to the proposed action, (the release of desalinated water) is the addition of GFD Project wells and gathering infrastructure that are approved under EPBC 2012/6615.

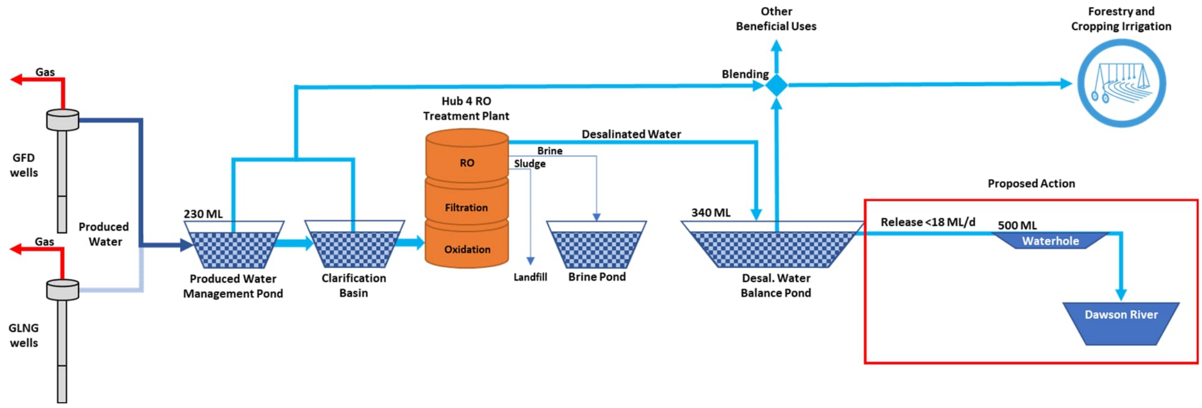

Figure 2-4 Conceptualisation of the GFD Project and proposed action

2.3.1 Desalinated release duration and frequency

Given the age of the gas field, it is expected that water rates will gradually decline over time. The proposed action seeks approval for 18 ML/day to align with existing authorisations and to maintain flexibility in project water management. The proposed action is proposed until 31 March 2066, consistent with the expiry of the GFD Project gas fields EPBC approval 2012/6615.

Forecast water volumes of GLNG vs GFD Project water are dynamic and regularly being updated (using a reservoir and GoldSim model) based on the most recent actual water production. Detailed water production under the GFD Project in the FPA is estimated from current production. Use of existing GLNG water production rates to forecast GFD is considered representative based on the overlapping nature of the GLNG and GFD Project wells and the same reservoir target formations. The ongoing operation of desalinated water releases will be reactive to gas field conditions, water production rates and availability of beneficial reuses (irrigation, dust suppression etc) based on climatic conditions at any given point in time. Overall inflow rates to HCS04 ROP are forecast to remain between 5.5 ML/day and 7.0 ML/day until 2032 after which a general decline in inflow is forecast, as observed in Figure 2-5.

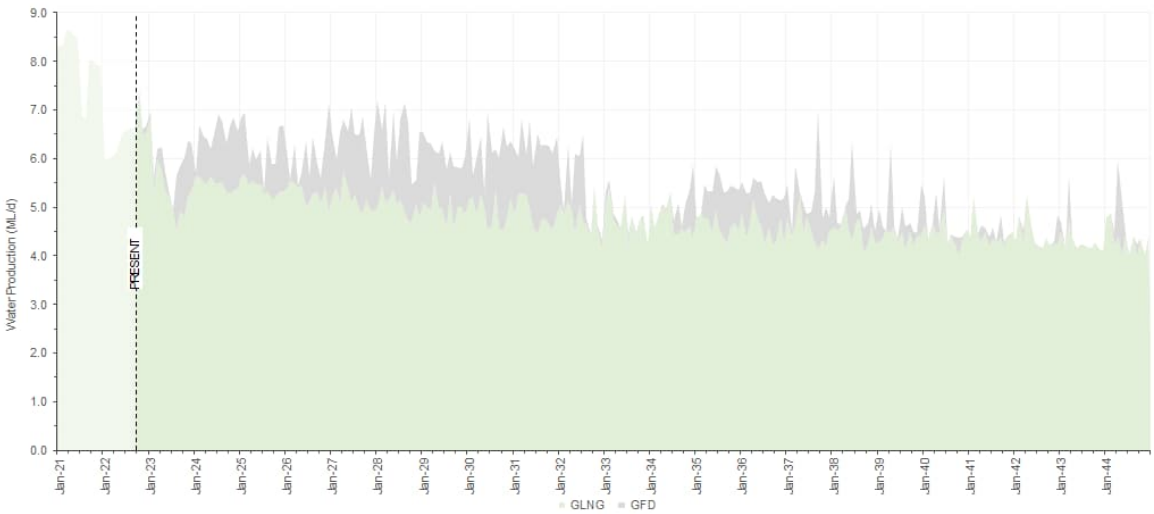

Figure 2-5 P50 model for HCS04 ROP cumulative inflow from GLNG (green) and GFD (grey) Projects

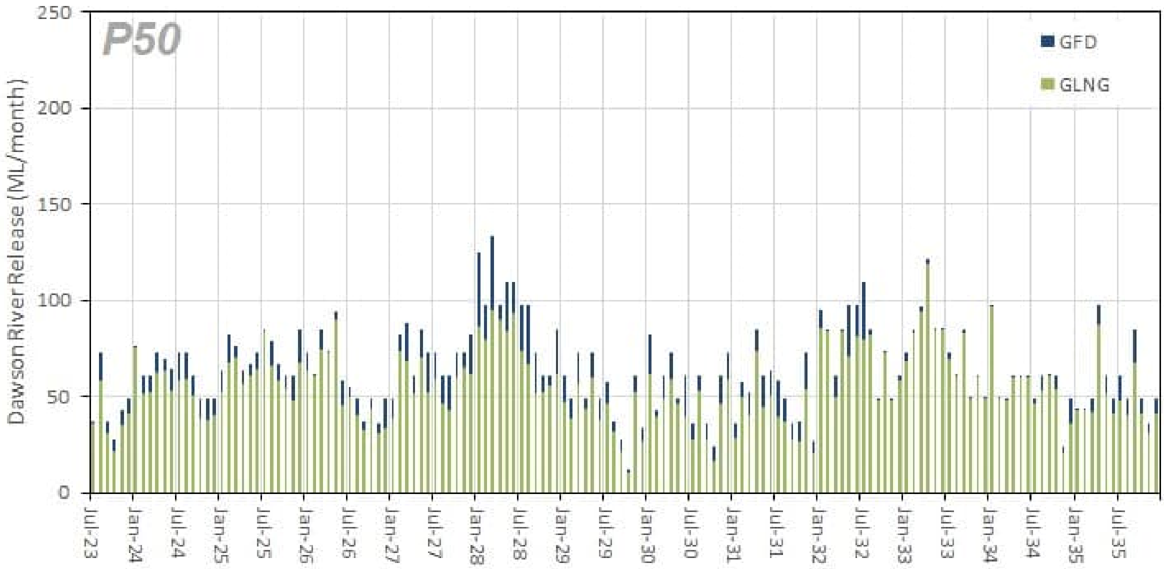

Figure 2-6 P50 Forecast monthly Dawson River release plot to 2035

Forecast of water management requirements and associated desalinated water requirements consider a range of climate change factors to assess future beneficial use and desalinated water discharge needs. Forecasts presented in Figure 2-5 and Figure 2-6 are based on the median (P50) climate change factor.

3.0 Matters of national environmental significance and environmental values

Chapter summary

MNES requiring assessment under the DAWE (2021) RFI are the listed threatened species *Elseya albagula* (white-throated snapping turtle), *Rheodytes leukops* (Fitzroy River turtle), groundwater dependent ecosystems (GDE) that is utilised by the listed threatened species or GDE that are listed in themselves as a threatened ecological community (TEC). The DAWE (2021) RFI also requested the proposed action assess water resources in relation to coal seam gas development.

Review of MNES mapping identified one TEC within and adjacent to the proposed action area; the regional ecosystem (RE) 11.3.2 - *Eucalyptus populnea* woodland on alluvial plains that contains a component RE of the listed Poplar Box Grassy Woodland on Alluvial Plains TEC (EPBC Act 1999 - Commonwealth). Additional GDE are assumed present within the proposed action area and have been assessed concurrently in the PD as part of the overall supporting ecosystem function supporting the two listed threatened species.

An ecohydrological conceptual model (ECM) was developed to identify the key ecohydrological functions and/or mechanisms that the MNES and TEC may have a significant risk from the ongoing intermittent release of desalinated water via the existing infrastructure, drainage feature, waterhole and Dawson River. The ECM was then updated following the impact assessment completed in this PD.

Assessment of the desalinated water release references a range of water and sediment quality criteria. These criteria are based on the respective environmental values (EV) identified for the proposed action area together with biological and riparian quality criteria developed from site specific baseline assessments. The baseline assessments were conducted between 2013 and 2015 as a requirement of the REMP, which is required by the State EA. A combination of site-specific data and national water and sediment quality guidelines are used for reference of significant change from baseline and upstream surface water and sediment quality.

3.1 Matters of national environmental significance

The 2021 DAWE RFI (Appendix A) identified the following Matters of National Environmental Significance (MNES) applicable for the proposed action:

- listed threatened species and communities (sections 18 and 18A), and their associated habitat and ecological communities, specifically:
  - the White-throated snapping turtle (*Elseya albagula*) – critically endangered
  - the Fitzroy River turtle (*Rheodytes leukops*) – listed as vulnerable
  - groundwater dependent ecosystems (GDE) utilised by the listed species or considered a threatened ecological community (TEC), and
- a water resource, in relation to coal seam gas development and large coal mining development (sections 24D and 24E).

A map of identified MNES in the proposed action area is presented in Figure 3-1.

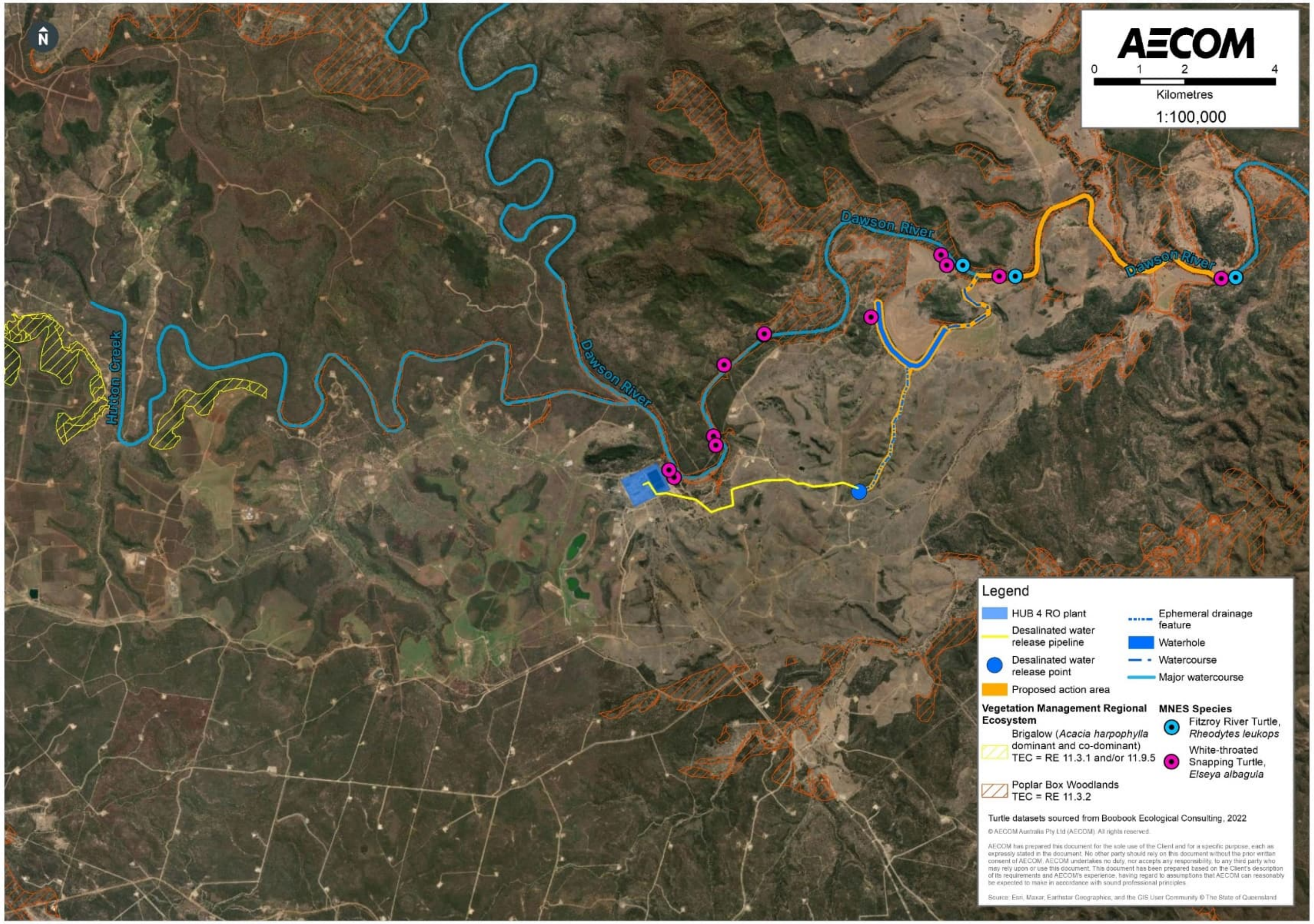

Figure 3-1 Dawson River identified MNES species

3.2 Ecohydrological model & complete pathways

Based on the identification of MNES turtles, GDE utilised by the listed species or considered a TEC, and water resources as the primary concerns to be assessed in the PD, an ecohydrological conceptual model (ECM) was developed. An ECM describes the relationships between elements of a proposed action, environmental processes, transport pathways for chemicals, ecological receptors and relevant exposure pathways linking the sources to the receptors.

The developed ECM for the proposed action consists of a combination of tables and conceptual illustrations to outline the applicable elements, pathways and processes for water resources, GDE and turtles. In general, if there is no viable pathway between an element of the proposed action (e.g. chemical or hydrological change) then a potential risks to ecological receptors cannot occur.

The proposed action is the (ongoing) release of up to 18 ML/day of desalinated water following treatment at the HCS04 ROP to a quality protective of aquatic ecosystems and drinking water environmental values, to an ephemeral drainage feature, waterhole, outlet watercourse and the Dawson River. The primary elements of the desalinated water release that are applicable to MNES, GDE and water resources are considered to include:

- risk of impacts to the natural chemical composition of the receiving environment, including groundwater, surface water and sediments
- risk of impacts associated with exposure and uptake from treated water by MNES turtles and GDE species that are TEC
- risk of impacts to natural hydrological regime of groundwater and surface waters.

Table 3-1 provides a summary of the key pathways and exposure/environmental process for MNES turtles, TEC and GDE associated with the proposed action. Figure 3-2 provides a general conceptual model of the proposed action, Figure 3-3 provides a visual ECM for water resources and GDE/TEC and Figure 3-4 provides a visual ECM for MNES turtles together with breeding periods (Panel C), base-flow Dawson River conditions (Panel D) and high/flood flow Dawson River conditions (Panel E).

A potential impact pathway is considered complete if there is a direct, observable, or measurable connection between a chemical, element, pathway, exposure mechanism and receptor. A complete pathway does not designate that a risk of undesirable impact occurs, but just allows the focus of the PD impact assessment on a particular element.

Table 3-1 Tabular ECM of the proposed action

Proposed Action Element	Impact pathway	MNES species/TEC and water resource exposure mechanism	Pathway completeness
Groundwater Resources			
Process and geogenic chemicals in desalinated water	Desalinated water releases to Upper Dawson River via the waterhole and ephemeral watercourse.	Changes to groundwater resource suitability for ecosystem function through discharge of desalinated water	Complete for shallow sediments Incomplete for deeper aquifers (Precipice Sandstone)
		Changes to groundwater resource availability for licensed abstraction through discharge of desalinated water	Incomplete for deeper aquifers Not Applicable for shallow sediments
Desalinated water discharge at up to 18 ML/day	Hydraulic change to groundwater resource availability	Reduction in availability of groundwater resources for beneficial uses	Complete for shallow sediments Incomplete for deeper aquifers (Precipice Sandstone)
Surface Water Resources			
Process and geogenic chemicals in desalinated water	Desalinated water releases to Upper Dawson River via the waterhole and ephemeral watercourse.	Significant change to surface water and hyporheic zone chemistry in waterhole, outlet watercourse and Dawson River	Complete
		Significant change to sediment chemistry in waterhole, waterhole outlet and Dawson River	Complete
		Significant accumulation of chemicals in sediments in waterhole, waterhole outlet, and Dawson River	Complete
Desalinated water discharge at up to 18 ML/day	Hydraulic change to essential MNES turtle habitat and TEC within Dawson River and proposed action area	Significant change to drainage feature, waterhole and Dawson River hydrological regime via increased flow depths and discharge under baseflow and flood conditions	Complete
		Significant erosion of beds and banks of drainage feature, waterhole, outlet watercourse and Dawson River	Complete
		Reduction in available water resource for licensed abstraction within proposed action area and downstream users	Complete
GDE and Threatened Ecological Communities			
	Desalinated water releases to Upper Dawson River via the	Uptake of chemicals by terrestrial GDE vegetation and potential changes to function and extent of ecosystem including	Complete

Proposed Action Element	Impact pathway	MNES species/TEC and water resource exposure mechanism	Pathway completeness
Process and geogenic chemicals in desalinated water	waterhole and ephemeral watercourse.	• RE 11.3.25 (*Eucalyptus tereticornis* or E. camaldulensis woodland fringing drainage lines) • RE 11.3.2 - Eucalyptus populnea woodland on alluvial plains	
		Uptake of chemicals by aquatic GDE vegetation and potential changes to function and extent of ecosystem including hyporheos, subterranean GDE and associated habitat within the waterhole and Dawson River sediments	Complete
Desalinated water discharge at up to 18 ML/day	Hydraulic change to GDE and TEC habitat via increase or decrease in seasonal water table change	Reduction or increase in water table elevation outside pre-existing range that may increase or decrease rootzone water availability impacting terrestrial and aquatic GDE vegetation extent	Complete
MNES turtles			
Process and geogenic chemicals in desalinated water	Desalinated water releases to Upper Dawson River via the waterhole and ephemeral watercourse.	Water and chemical ingestion via direct and incidental ingestion during feeding.	Complete
		Dermal and internal villi contact with desalinated water containing chemicals and uptake via uptake of soluble and bioavailable chemicals for juvenile and adult turtles.	Complete
		Direct ingestion of chemicals from typical turtle food - algae, vegetation and macroinvertebrates.	Complete
		Direct contact of eggs with desalinated water during dry season nesting period on high sand bars and high banks.	Complete
Desalinated water discharge at up to 18 ML/day	Hydraulic change to essential MNES turtle habitat within Dawson River.	Change in riffle and run flow depth and velocity as areas of foraging and pools as areas of foraging and refuge.	Complete
		Inundation and/or erosion of sand banks and high banks used for nesting during desalinated water releases.	Complete

Notes
Complete = source, migration pathway, receptor and an exposure (S-P-R-E) mechanism are all present (note – an pathway can be complete but may not pose a risk e.g. if a chemical is below a toxicity threshold)
Incomplete = one of the above is absent and the S-P-R-E linkage is incomplete
Plausible = there is insufficient information to determine if the S-P-R-E linkage is complete or incomplete i.e. a data gap exists that requires information
* - Significance based on Significant Impact Guidelines 1.3 (SIG 1.3)
TBD – Significance is assessed at the completion of each section and included in a revised ECM

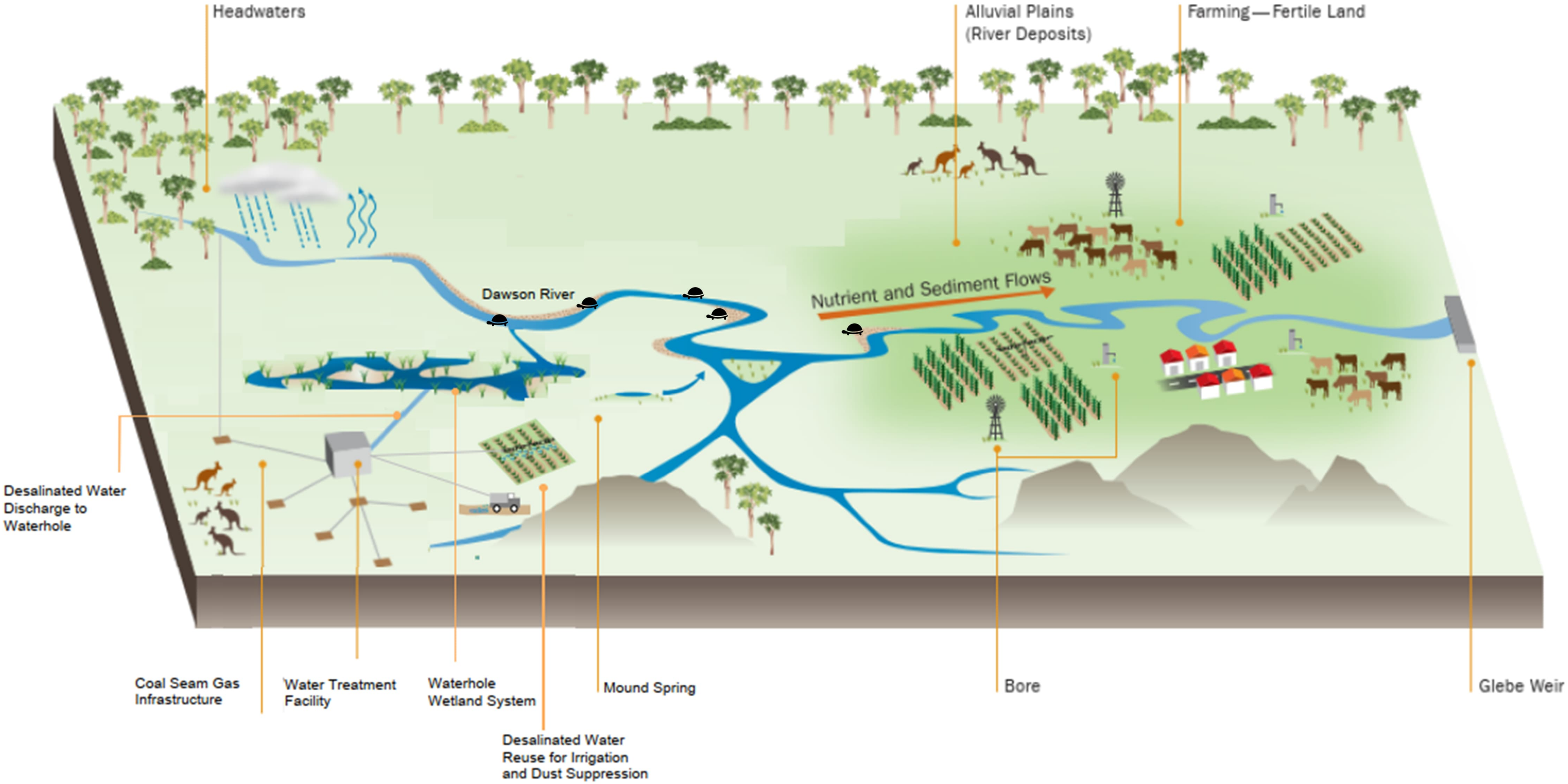

Figure 3-2 Overview conceptual model of the proposed action area and surrounding areas

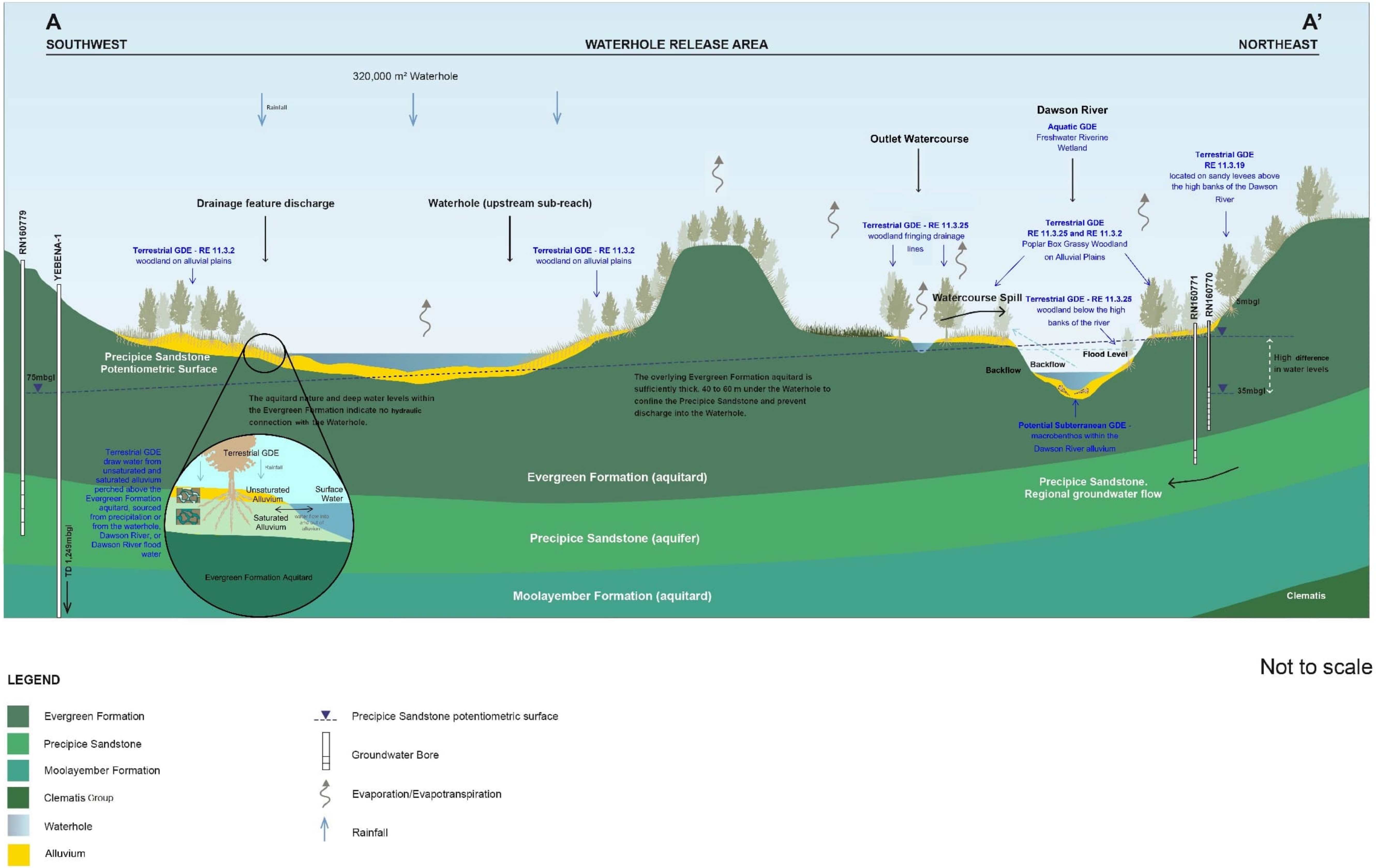

Figure 3-3 Ecohydrological model for groundwater resources and GDE associated with the waterhole and Dawson River (Panel A)

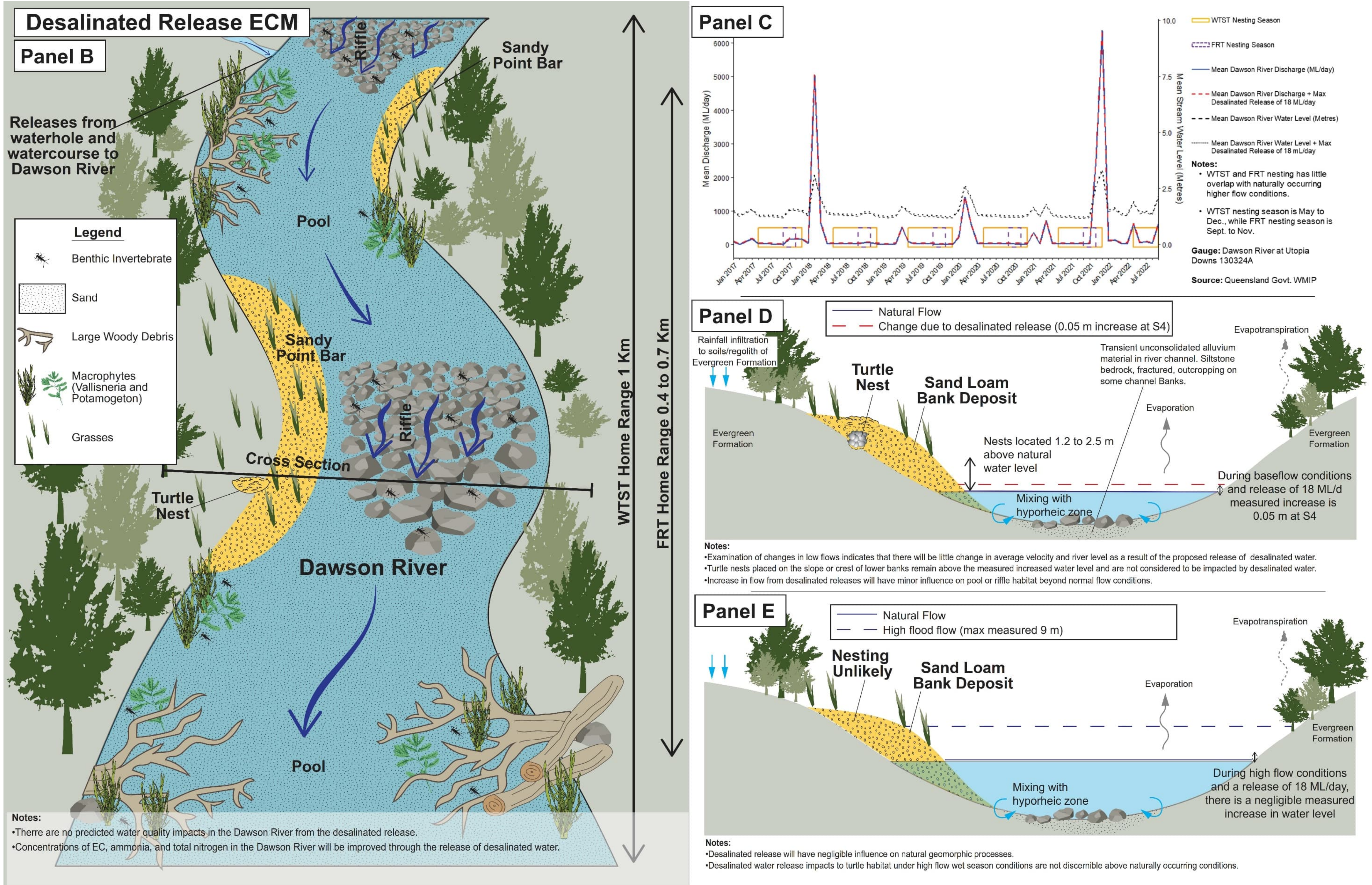

Figure 3-4 Ecohydrological model for MNES turtles (Panels B to E)

3.3 Applicable environmental values

In addition to MNES and receptors defined in the ECM the *Queensland Environmental Protection Act, 1994* defines Environmental Values (EV) to be protected for Queensland water in subordinate policies. For Queensland surface waters and groundwater, the Environmental Protection (Water and Wetland Biodiversity) Policy (EPP WWB) (2019) defines:

- Scheduled EV that apply to a sub-regional catchment waters such as the Dawson River
- the management intent for waters such as moderately disturbed (MD) and
- water quality objectives (WQO) that are intended to maintain or improve the condition of system.

The *Environmental Protection (Water) Policy, 2009*[9] *Dawson River Sub-basin Environmental Values and Water Quality Objectives Basin No. 130 (part), including all waters of the Dawson River Sub-basin except the Callide Creek Catchment: September 2011* (EPP Water: Dawson River Sub-basin) identifies the EVs for the Upper Dawson River (main channel) surface water environment as summarised in Table 3-2 below. Table 3-2 also includes assessment of Scheduled EV applicability to the waterhole and Dawson River in the proposed action area.

Table 3-2 Assessment of Environmental Values for the receiving environment

Environmental Value	Applicability to Upper Dawson River Main Channel Surface Water Resource[A]	Santos assessed applicability[B]	
		Waterhole	Dawson River
Aquatic ecosystems	Applicable[C]	Applicable – moderate	Applicable – moderate to high
Irrigation	Applicable	Not applicable	Applicable – low
Farm supply/use	Applicable	Not applicable	Applicable – low
Stock water	Applicable	Applicable – high	Applicable – high
Aquaculture	Not applicable	Not applicable	Not applicable
Human consumer	Applicable	Applicable – low	Applicable – low
Primary recreation	Applicable	Applicable – low	Applicable – low
Secondary recreation	Applicable	Applicable – low	Applicable – low
Visual recreation	Applicable	Not applicable	Not applicable
Drinking water	Applicable	Not applicable	Applicable – low
Industrial use	Applicable	Not applicable	Not applicable
Cultural and spiritual values	Applicable	Applicable – moderate	Applicable – high

Notes:
[A] EVs for Upper Dawson main channel (downstream of Hutton Creek junction) – developed areas, including Glebe Weir (EHP, 2011)
[B] frc environmental, 2016b
[C] Applicability is based either on the presence of a license to carry out the EV (e.g. irrigation) or public access to the water to carry out an EV (e.g. primary recreation)

An assessment of existing users of surface water resources throughout the proposed action area was undertaken to identify associated human EVs; this included analysis of water entitlement data available from the former Department of Natural Resources, Mines and Energy (DNRME), now Department of Resources (DoR). For the Upper Dawson River, the predominant uses of surface water were identified as livestock and domestic supply, with approximately 0.3% allocated to town water supply (Santos, 2014).

[9] Now the *Environmental Protection (Water and Wetland Biodiversity) Policy, 2019*

Surface water entitlements for the Dawson River (as current November 2022) are illustrated on Figure 3-5. The drinking water and irrigation EV's have been conservatively considered applicable despite being located outside the proposed action area, as per the assessment presented in Table 3-3.

Table 3-3 Assessment of scheduled EVs conservatively assessed as applicable to the proposed action

Environmental Value	Applicability to proposed action
Drinking water	There is no licenced (or known) extraction of water for drinking or human consumption purposes from the Dawson River or waterhole within the proposed action area. As shown in Figure 3-5, a search of the Business Queensland water entitlement viewer[10] indicates that the closest surface water domestic supply entitlement (Licence 37127S) is located approximately 244 km downstream of the existing desalinated water release location at Theodore for domestic supply and drinking water following treatment. Due to the use of Dawson River water for town supply drinking water remains the primary EV to be protected under the State EA.
Irrigation	There is one licence for irrigation water (License No 14134S) located approximately 71 km downstream of the existing desalinated water release location, noting this licence provides authority to extract from an 'Unnamed tributary of the Dawson River', not the Dawson River. The Glebe Weir is located 156 km downstream of Yebna and is used for supply of water under the GBUS for use by irrigators.
Stock Water	The nearest surface water domestic supply entitlement (Licence 37127S) is located approximately 244 km downstream of the existing desalinated water release location
Agriculture	There is one license to take water for agriculture from the Dawson River (Licence 618828) within the proposed action area by the adjacent land owner (Figure 3-5).
Dawson Water Supply Scheme	A water supply scheme is located in the Dawson River located approximately 250 km downstream of the proposed action (Figure 3-5), extending from upstream of Theodore to downstream of Boolburra.

These MNES and EVs and the potential for impact as a result of the proposed action are assessed in this PD against the applicable EPBC significant impact criteria derived from the following documents:

- Significant Impact Guidelines 1.1 (Matters of National Environmental Significance)
- Significant Impact Guidelines 1.3 (Coal seam gas and large coal mining developments – Impacts on water resources)

A summary of the respective significant impact assessment outcome is provided in:

- Section 4.4.5 for groundwater resources
- Section 5.5.7 for surface water resources
- Section 7.2.5 for MNES turtles and
- Section 6.4.7 for groundwater dependent ecosystems (GDE).

[10] Water entitlement viewer | Business Queensland

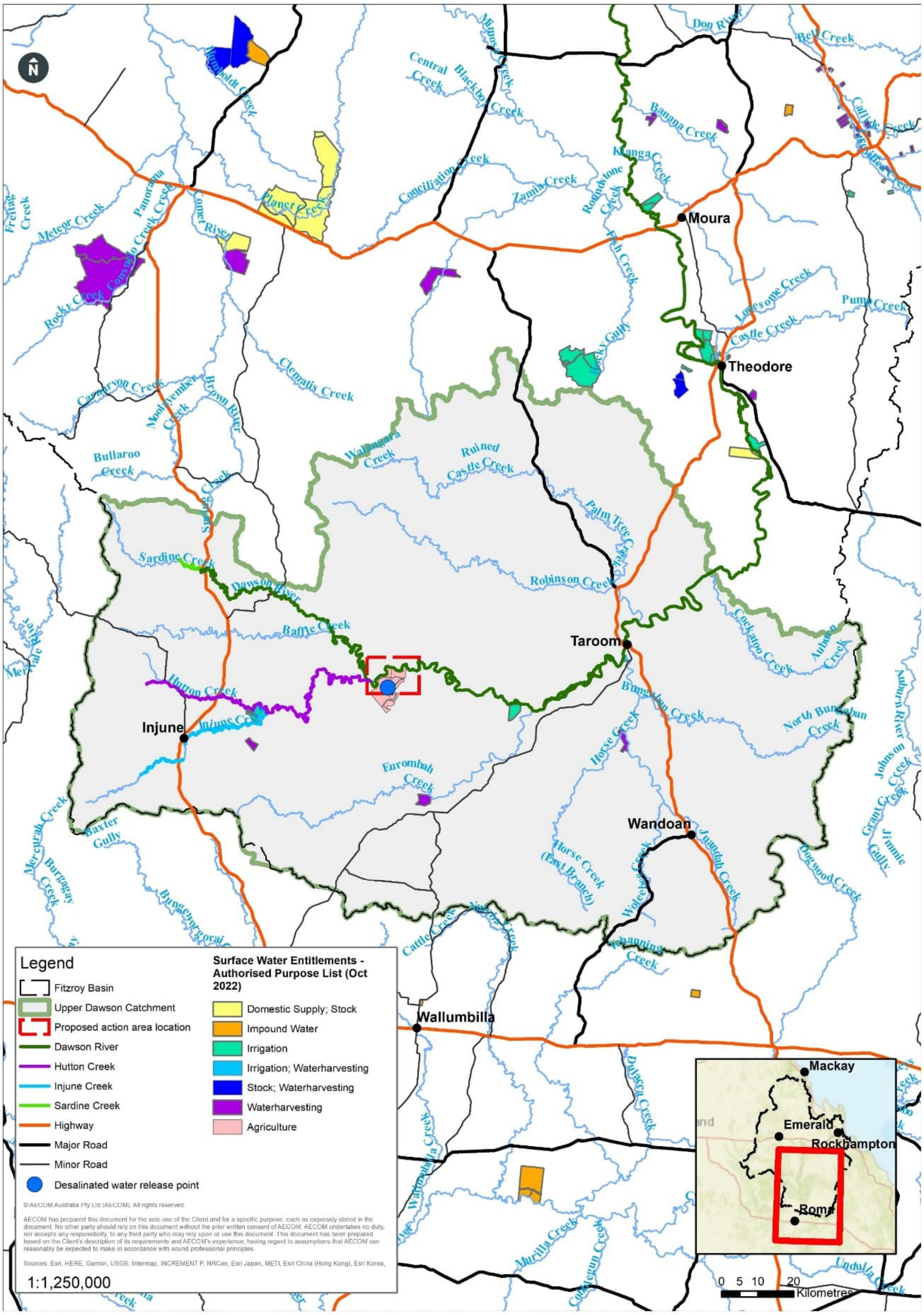

Figure 3-5 Dawson River water entitlements 2022

3.4 Screening criteria

Assessment of potential impact of an action on EV is completed via comparing environmental data (indicators), such as water quality or ecological data, against various Screening criteria. These can be "guideline" values and/or "trigger" values and/or sub-regional water quality objective (WQO) that are applicable for a specific EV such as ecosystem protection, drinking water, irrigation etc. If the data collected is above screening criteria either individually or as either median value (physicochemical parameters) or the 95th percentile (toxicants) of a long-term data set it does not mean that an unacceptable impact is occurring but that additional lines of evidence need to be assessed such as the nature of the receptor, indicator trends or the spatial context of the change observed in monitoring data (ANZG, 2018). The uncertainty in identifying actual impact occurring is due to the application of safety factors in screening criteria development for water quality guidelines.

The State EA specifies maximum concentrations (contaminant limits) for desalinated water in the DWB pond prior to discharge and at location S4 (Yebna Crossing) as the compliance point for the project. The State EA also requires Santos to conduct a REMP that measures environmental media (water, sediments, habitat, macroinvertebrates fish etc) "…*to monitor, identify and describe any adverse impacts to surface water environmental values, quality and flows due to the authorised activity(ies).*" The REMP is described in more detail in Section 9.0 with annual reports provided in Appendix F and the REMP design report is provided in Appendix J.

Collected data from the REMP is compared against a combination of Local Trigger (LT) values developed from baseline monitoring conducted in the proposed action area between 2013 and 2015 and Queensland specific values and national values/guidelines as described in the following section as summarised in Table 3-4 and Table 3-5.

3.4.1 Surface water quality objectives and guideline values

The EPPWWB states that the EVs for water are the qualities of water that make it suitable for supporting aquatic ecosystems and human water uses such as drinking water, stock water, irrigation. The EPP Water: Dawson River Sub-basin specifies water management goals, sub-regional WQO and guideline values for a range of EV. Water management goals are specified levels of protection for a water body under the policy, for example:

- High Ecological Value (HEV) is applied for areas with minimal disturbance (e.g., National Parks, State Forests), and/or
- Moderately Disturbed (MD) is applied to areas where the natural environment has been disturbed by human activity to a relatively small but measurable degree; commonly applied to rural areas where natural vegetation has been cleared for agricultural use.

Water management goals and sub-regional WQO are long-term goals based on narrative statements of indicators or numerical concentration levels established for receiving waters (for WQO) to support and protect the designated EVs for those waters. They are based on scientific criteria but maybe modified by other inputs (e.g., social, cultural, economic).

Schedule 1 of the EPP WWB defines the sub-regional WQOs and Guideline Values (via cross reference to guideline documents for an applicable EV) for surface waters within the Dawson River for scheduled EVs of both surface waters and groundwater at the sub-regional level. The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG -2018) define a guideline value as "...*as a measurable quantity (threshold) or condition of an indicator for a specific community value below or, for some stressors, above which we consider to be a low risk of unacceptable effects occurring.*" The ANZG (2018) also state that guideline values applicable to the local conditions or situation should be used.

Whilst sub-regional WQO are often derived from regional data for physicochemical parameters and are considered to be applicable at a sub-regional and catchment level they are also aspirational in line with the management goal. Sub-regional WQO may not be representative of conditions in individual catchments where site specific data is more applicable.

ANZG (2018) defines three ecosystem conditions/levels of protection for aquatic ecosystems, however Queensland has expanded this to four levels of protection by splitting 'slightly to moderately disturbed' into 'slightly disturbed' and 'moderately disturbed'. The EPP Water Dawson River Sub-basin (Table 2) lists the management intent (level of protection) for the Upper Dawson River as 'Aquatic ecosystem – moderately disturbed'. For toxicants, this corresponds to 95% species protection level as per the ANZG (2018).

SSWQG were derived for boron for both aquatic ecosystems and irrigation EVs in accordance with ANZG (2018) methodology:

- A revised SSWQG of 2.9 mg/L for dissolved boron was calculated based on direct toxicity assessment in accordance with ANZG (2018) and detailed in *Revised Boron Site-Specific Water Quality Criterion - Dawson River Release Scheme* (AECOM 2019). This concentration is below a limit at which both ecologically meaningful changes are not expected to occur and whereby existing ecosystem conditions will be maintained, and
- A revised locally derived SSWQG for boron of 1.2 mg/L was calculated where the irrigation EV is considered applicable. The SSWQG was calculated in accordance with ANZG[11] (2018) as detailed in *Risk Assessment Report, Boron Irrigation Water Guidelines Deviation, Fairview Project Area* (EHS Support, 2019). This SSWQG represents the thresholds below which there should be minimal risk of adverse effects to crop and soil health and takes into consideration mixing of the maximum aquatic ecosystem boron SSWQG.

The State EA provides CL for a range of physicochemical and chemical parameters for desalinated water in the HCS05 DWB pond prior to release (Schedule B, Table 4) and the receiving environment based on sampling completed at the monitoring station S4 at Yebna Crossing (Schedule B, Table 5). Contaminant limits specified in Schedule B Table 4 and Table 5 are designated to protect the Drinking Water EV for the Dawson River.

These contaminant limits generally reflect sub-regional WQOs provided in the EPP Water Dawson River Sub-basin with some exceptions, including the boron SSWQGs and physicochemical parameters such as nutrients or total dissolved solids (TDS). Table 3-4 provides the respective value from the respective sources referenced in this section.

For the purposes of assessing impact of the proposed action under the EPBC Act (1999) to identified MNES and water resources of the Dawson River, the following screening levels have been adopted:

1) Contaminant Limits (CL) specified in Schedule B, Table 4 (for desalinated water) and Table 5 (for the S4 compliance point) of the State EA
2) REMP Local Trigger (LT) value for water quality[12], sediments and local biological objective (LBO) for macrobenthos, crustaceans and fish defined from baseline monitoring of the waterhole and Dawson River prior to the start of desalinated water releases
3) applicable site-specific water quality guidelines (SSWQG) developed for boron (AECOM, 2019).
4) Sub-regional WQOs defined for Schedule 1 of EPP Water: Dawson River Sub-basin
5) ANZG (2018) 95% species protection level default guideline value (DGV) for freshwater and
6) ANZG (2018) Default Guideline Values (DGV) for sediments.

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[11] The boron irrigation SSWQG was derived in accordance with Guidance provided in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Volume 3: Primary Industries – Rationale and Background Information (2000). The ANZG (2018) defer to the 2000 publication for irrigation water and SSWQG methodology.

[12] The Santos Ltd Dawson River Desalinated Release Receiving Environment Monitoring Program (2022) provides local trigger (LT) values for parameters that do not have a State EA CL. Where referenced in this assessment the REMP LT is provided in parenthesis e.g. (12)

Table 3-4 State EA CL/REMP LT, WQO and DGV for the proposed action area waters

Parameter Chemical	Unit	Contaminant Limit DWB Pond	Contaminant Limit S4 compliance point	Sub-regional WQO/DGV[a]
Temperature	C	Monitor Only	NL	NL
pH	pH	6.5-8.5	NL	6.5-8.5
Electrical Conductivity	µS/cm	370 (75th %ile) 500 (max)	NL	<370 (base flow) <210 (high flow)
Turbidity	NTU	50	NL	50
Suspended Solids	mg/L	NL	NL	<30
Dissolved Oxygen	mg/L	6.4-16.1	NL	85-110%
Total Nitrogen	µg/L	620	NL	620
Alpha activity	Bq/L	NL	0.5	NL
Beta activity	Bq/L	NL	0.5	NL
Ammonia	mg/L	0.9	0.5	0.02
Calcium	mg/L	>1	NL	NL
Chloride	mg/L	175	NL	NL
Fluoride	mg/L	1	1.5	NL
Iodide	mg/L	NL	0.5	NL
Magnesium	mg/L	Monitor Only	NL	NL
Potassium	mg/L	Monitor Only	NL	NL
Sodium	mg/L	115	NL	NL
Sulphate	mg/L	5	NL	<5
Antimony (dissolved)	µg/L	NL	3	9
Aluminium (dissolved)	µg/L	55	200	0.8 (<6.5 pH 55 (>6.5 PH)
Total arsenic	µg/L	13	NL	NL
Arsenic (dissolved)	µg/L	NL	10	24 (AsIII) 13 (AsV)
Barium (dissolved)	µg/L	NL	2,000	NL
Boron (dissolved)	mg/L	2.9 @ 18 ML/day 2.5 @ 13.5 ML/day	4 2.9 (Dawson River (MP1)	0.94
Bromide (dissolved)	µg/L	NL	7,000	NL
Cadmium (dissolved)	µg/L	0.2	2	0.2
Chromium (VI) (dissolved)	µg/L	1	50	1.0
Cobalt (dissolved)	µg/L	NL	NL	1.0
Copper (dissolved)	µg/L	1.4	2,000	1.4
Cyanide	µg/L	NL	80	7
Iron (dissolved)	µg/L	300	NL	NL

Parameter Chemical	Unit	Contaminant Limit DWB Pond	Contaminant Limit S4 compliance point	Sub-regional WQO/DGV[a]
Lead (dissolved)	µg/L	3.4	10	3.4
Manganese (dissolved)	µg/L	1,900	500	1,900
Mercury (dissolved)	µg/L	0.6	1	0.6
Molybdenum (dissolved)	µg/L	NL	50	34
Nickel (dissolved)	µg/L	11	20	11
Selenium (dissolved)	µg/L	11	10	11
Silver (dissolved)	µg/L	NL	100	0.05
Strontium (dissolved)	µg/L	NL	4,000	NL
Zinc (dissolved)	µg/L	8	3,000	8
Hardness	mg/L	Monitor Only	NL	NL
PAH (as BaP TEF)	µg/L	NL	0.01	0.1
TPH	µg/L	NL	200	NL
Benzene	µg/L	NL	1	950
Ethylbenzene	µg/L	NL	300	80
Toluene	µg/L	NL	800	180
Xylenes	µg/L	NL	600	75 (m-xylene)
Bisphenol A	µg/L	NL	200	NL
Nonylphenol	µg/L	NL	500	NL
N-Nitrosodimethylamine	µg/L	NL	0.1	NL
Trihalomethanes (THM): Bromodichloromethane Bromoform Chloroform (Trichloromethane) Dibromochloromethane	µg/L	NL	250	770 (Chloroform)

Notes
[a] – The sub-reginal WQO for toxicants references the Australian Water Quality Guideline (2018) Default Guideline Value where a WQO is not directly referenced in the WQO table
NL – No contaminant limit specified
TPH – Total Petroleum Hydrocarbons
PAH – polynuclear aromatic hydriocarbons

The assessment of water quality in the proposed action area references the respective contaminant limit, WQO, DGV or SSWQG. Table 3-5 summarises the assessment format for contaminant limits, WQO, DGV and SSWQG that are used in this PD for assessing water quality impacts.

Table 3-5 Assessment of site data against a WQO, DGV and SSWQG for MD waters

Parameter Type	Assessment	Source
Physicochemical parameters - dissolved oxygen (DO), electrical conductivity (EC), salinity, total suspended solids (TSS)	Median (50th percentile) value of a physicochemical parameter at a sampling location from five or more independent samples should not exceed the specified State EA CL, LT value or sub-regional WQO percentile range for DO and pH, or	DES, 2022.

Parameter Type	Assessment	Source
Nutrients and Toxicants	95th percentile of a parameter (nutrient and toxicant) data set should not exceed the respective State EA CL, LT value, SSWQG or sub-regional WQO	ANZG, 2018.

Where a parameter 50th percentile is outside the specified range or above 95th percentile it does not indicate a non-compliance or unacceptable impact. Exceedances of a WQO or DGV trigger additional review of data including, but not limited to:

- review of the statistical data distribution to validate underlying assumptions of normal data distribution or sufficient data to calculate a meaningful percentile
- review of time series data to assess if the exceedance is associated an individual high concentration followed by a return to low concentrations that may not indicate a significant exceedance
- review of time series data to assess if the exceedance is associated with a more persistent level above a specified WQO or DGV
- review of the data against locally derived data for a parameter at a site-specific level
- Review of additional or alternate indicators or lines of evidence.

Where assessing a potential change from a baseline dataset (in lieu of a reference site), the ANZG (2018) states that the median (50th percentile) value of a physicochemical parameter or chemical should be below the 80th percentile of the baseline or upstream reference data set. This process has been adopted for comparison of baseline water quality data (generally 2012 to May 2015) against post desalinated water release data (June 2015 to June 2022) and when comparing upstream reference site data against downstream data in Section 5.3 and is included in summary statistics for monitoring locations in Appendix E.

3.4.2 Biological guidelines

The DES Monitoring and Sampling Manual: Environmental Protection (Water) Policy (2009) provides guidance on biological (macroinvertebrates and fish), aquatic habitat and riparian assessment for Queensland waters. The State EA requires a REMP to be developed for the GLNG Project (Requirement B36). The REMP requires the monitoring of "*biological indicators in accordance ANZECC & ARMCANZ 2000 (including Before, After, Control, Impact (BACI) Principal) and, where possible, consistent with methodologies specified by FRC Environmental Pty Ltd in their report titled Santos Coal Seam Gas Fields Aquatic Ecology Impact Assessment*."

Baseline assessments of biological elements including macrobenthos, riparian habitat and fish species (native and exotic) have been completed prior to the GLNG Project to inform baseline conditions to be referenced in the REMP developed as a requirement of the State EA (Appendix J). Zooplankton have been monitored under the REMP from 2018, however there is no WQO specified for the Upper Dawson River and no LBO in the REMP.

Details of the collection methodology for macroinvertebrates, crustaceans and fish can be found in the REMP development report in Appendix J. Table 3-6 defines the LBO applied in this assessment and Table 3-7 summarises the biological baseline indicators for the proposed action as per the State EA required REMP.

Table 3-6 Local biological objective

Ecological Index	Definition
Macroinvertebrates	
Abundance	The total number of individuals in a sample.

Taxonomic Richness	The number of taxa (in this assessment, generally families) and is a basic, unambiguous and effective diversity measure. It is affected by arbitrary choice of sample size. Where all samples are of equal size, taxonomic richness is a useful tool when used in conjunction with other indices. Richness does not take into account the relative abundance of each taxon, so rare and common taxa are considered equally.
PET Richness	Plecoptera (stoneflies), Ephemeroptera (mayflies), and Trichoptera (caddisflies) are referred to as PET taxa, and they are particularly sensitive to disturbance. There are typically more PET families within sites of good habitat condition and water quality than in sites of degraded condition. The lower the PET score the greater the inferred degradation.
SIGNAL-2 Score	Is based on the sensitivity of each macroinvertebrate family to pollution or habitat degradation. Each macroinvertebrate family has been assigned a grade number between 1 and 10 based on their sensitivity to various pollutants, and SIGNAL-2 scores are weighted for abundance. A low number means that the macroinvertebrate is tolerant of a range of environmental conditions, including common forms of water pollution (e.g. suspended sediments and nutrient enrichment).
Fish	
Native fish Observed : Expected Ratio	The richness of native and exotic fish species is the observed number of species compared to the expected number of species for that water type presented as a ratio. Where the ratio >1, then it is considered that there has been no impact to fish. Where is ratio <1, then the diversity of fish is lower than expected.
Exotic/Alien fish	The percentage of alien fish index is the number of alien fish individuals expressed as a percentage of the total number of individuals caught.
Macrocrustacean exoskeleton	
No. Species	The number of macrocrustacean species.
Exoskeleton Condition/Density	Exoskeleton condition/density of crustacean taxa assesses potential risk associated with low ion concentrations (e.g. calcium) on the ability of these taxa to mineralise exoskeletons.
Definition Source • frc environmental 2022 (Appendix J) • DES 2018 - Monitoring and Sampling Manual: Environmental Protection (Water) Policy 2009	

Table 3-7 Biological monitoring WQO and LBO

Ecological Index	Upper Dawson River sub-regional WQO	REMP Local Biological Objective (LBO)	
		Waterhole	Dawson River
Macroinvertebrates			
Abundance	-	92.3 – 252.8	39.9 - 152.0
Taxonomic Richness	23-33[e]	5.67 – 10.8	9.93 - 16.9
PET Richness	2-5[e]	0.0 – 1.2	1.47 - 4.0
SIGNAL-2 Score	3.31-4.2[e]	2.65 – 3.20	3.46 - 4.00
Fish			
Native fish Observed : Expected Ratio	≥1	≥1	≥1
Exotic/Alien fish	No increase	<2	<2
Macrocrustacean exoskeleton			
No. Species	-	Monitor Only	Monitor Only
Condition/density	-	good/soft	good/soft

Notes
Local Biological Objective is the 20th percentile and 80th percentile from baseline surveys collected over 7 surveys between 2013 and 2015 (frc environmental 2022)
Biological WQO are presented as the median value calculated from seven transects (refer to Appendix J)
[e] – edge habitat
Zooplankton are monitored under the REMP from 2018 onwards. In the absence of a WQO and LBO zooplankton are not assessed in this PD

3.4.3 Sediment quality guidelines

Some chemicals can partition to and accumulate in aquatic sediments. In some cases, these chemicals can pose an ecological risk to aquatic organisms, in particular benthic organisms which reside in and ingest sediments.

ANZG (2018) provide sediment quality criteria for a suite of contaminants. These criteria comprise "DGV" levels (above which ecological effects are possible), and "DGV-high" levels, above which ecological effects are probable. Referenced sediment DGV and DGV-high levels referenced in this PD are provided in Table 3-8 below.

REMP sediment monitoring references the ANZG (2018) DGV where present. Where a chemical is not specified in the ANZG (2018) the REMP Local Trigger (LT) is derived from the 80th percentile of the baseline sediment monitoring program.

Table 3-8 Sediment Quality Criteria used for screening potential significant impacts.

Toxicant	ANZG (2018) Guideline		REMP Local Trigger (LT) Value	
	DGV	DGV-high	Waterhole	Dawson River
Metals and Metalloids (mg/kg dry weight)[a]				
Aluminium	No DGV	No DGV	13,933	5,191
Antimony	2.0	25	No Trigger	
Arsenic	20	70	20	20
Boron	No DGV	No DGV	18.8	17.9
Cadmium	1.5	10	1.5	1.5
Chromium	80	370	80	80
Copper	65	270	65	65

Toxicant	ANZG (2018) Guideline		REMP Local Trigger (LT) Value	
	DGV	DGV-high	Waterhole	Dawson River
Iron	No DGV	No DGV	17,867	9,353
Lead	50	220	50	50
Manganese	No DGV	No DGV	648	230.5
Mercury	0.15	1.0	0.15	0.15
Nickel	21	52	21	21
Selenium	No DGV	No DGV	1	1.73
Silver	1.0	4.0	No Trigger	
Zinc	200	410	200	200
Organometallics (µg/kg dry weight, 1% OC)[c, d]				
Tributyltin (as Tin)	9.0	70	No Trigger	
Organics (µg/kg dry weight, 1% OC)[b,c]				
Total PAHs[e]	10,000	50,000	No Trigger	
Total DDT	1.2	5.0		
p.p'-DDE	1.4	7.0		
o,p'- + p,p'-DDD	3.5	9.0		
Chlordane	4.5	9.0		
Dieldrin[f]	2.8	7.0		
Endrin[f]	2.7	60		
Lindane	0.9	1.4		
Organics (mg/kg dry weight)[b]				
Total PCBs[g]	34	280	No Trigger	

DDD = dichlorodiphenyldichloroethane; DDT = Dichlorodiphenyltrichloroethane; DDE = dichlorodiphenyldichloroethylene; DGV = default guideline value; GV-high = additional upper guideline value; PAHs = polycyclic aromatic hydrocarbons; PCBs = polychlorinated biphenyls; TPHs = total petroleum hydrocarbons; OC = organic carbon

a. Primarily adapted from the effects range low (ERL) and effects range median (ERM) values of Long et al. (1995).

b. Primarily adapted from threshold effects level (TEL) and probable effects level (PEL) values of MacDonald et al. (2000) and CCME (2002).

c. Normalised to 1% OC within the limits of 0.2 to 10%. Thus if a sediment has (i) 2% OC, the '1% normalised' concentration would be the measured concentration divided by 2, (ii) 0.5% OC, then the 1% normalised value is the measured value divided by 0.5, (iii) 0.15% OC, then the 1% normalised value is the measured value divided by the lower limit of 0.2.

d. Basis of revision is described in Appendix A2 of Simpson et al. (2013a).

e. The DGV and GV-high values for total PAHs (sum of PAHs) include the 18 parent PAHs: naphthalene, acenaphthylene, acenaphthene, fluorene, anthracene, phenanthrene, fluoranthene, pyrene, benz[a]anthracene, chrysene, benzo[a]pyrene, perylene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[e]pyrene, benzo[ghi]perylene, dibenz[a,h]anthracene and indeno[1,2,3-cd]pyrene. Where nonionic OCs like PAHs are the dominant chemicals of potential concern (COPCs), the use of equilibrium partitioning sediment benchmarks (ESBs) is desirable, which includes a further 16 alkylated PAHs (generally listed as C1-/C2-/C3-/C4-alkylated), as described in Appendix A3 of Simpson et al. (2013a).

f. Where dieldrin or endrin are the major COPCs, it is recommended that ESB approaches are applied as described in Appendix A4 of Simpson et al. (2013a).

g. Origin described in Appendix A5 of Simpson et al. (2013a).

4.0 Groundwater

Chapter summary

Review of potential impacts of the proposed action on groundwater resources has referenced empirical data from baseline studies, the REMP, publicly available regional aquifer assessment data (Office of Groundwater Impact Assessment (OGIA)) data and Surat Basin UWIR underground water impact report.

Under baseflow conditions hydrogeochemistry indicates the main source of surface water within the Dawson River is from the Precipice Sandstone discharge upstream of the proposed action area.

An assessment of the geology and groundwater resources indicates that the proposed action will occur in an area underlain by the Evergreen Formation, an aquitard that separates the Precipice Sandstone and surface water in the waterhole and Dawson River within the proposed action area. Due to the low permeability of the underlying Evergreen Formation, there is no hydraulic connection between the underlying Precipice Sandstone and surface water in the proposed action area.

Desalinated water will discharge to the Dawson River via an ephemeral gully and waterhole. The Dawson River contains transient in-channel alluvium with limited thickness, continuity (due to bedrock outcrops), and effective storage above the prevailing water level within the Dawson River. These alluvium deposits are not considered a consistent aquifer from a groundwater resource perspective. An assessment of the desalinated water releases, that is treated to drinking water quality criteria as required under the State EA to protect the aquatic ecosystem and drinking water Environmental Values (EV) of the Dawson River, is considered not to unacceptably impact groundwater resources.

The potential impact of desalinated water releases to alter hyporheic water because of advective exchange within the transient riverbed sediments were found to have less than 10% increase in baseflow. Directly measured increases in the Dawson River level at Yebna Crossing (S4) increase by no more than 0.05 m under baseflow conditions, which is insignificant when compared to the natural variation.

Thus, the proposed action discharge, resulting in a temporary increase in total river flow and minor rise in surface water elevations, is considered to have little or no potential for advection due to only a 0.03 m to 0.05 m zone, minimal change in water quality (above and below the Dawson River – waterhole confluence), and the regular flushing of alluvium (assuming it remained in situ) during higher flow events. The potential advection impact is, based on available information and the dynamic nature of the Dawson River system, not considered to be accumulative, wide reaching, or significant.

This section provides the information requested relevant to desalinated water releases (event-based releases are no longer included in the proposed action), within the original RFI (Appendix A), IESC requirements (revised cross-reference table within Appendix C-1), and DCCEEW and IESC comments received on the initial PD (response tables within Appendix B2 and Appendix C-2 respectively).

The DAWE RFI (Appendix A) requested additional information relating to potential groundwater impacts associated with the proposed action as summarised below and Appendix B, specifically:

- potential impacts to groundwater resources via groundwater and surface water connectivity associated with the proposed action, and
- the potential impacts of groundwater to surface water connectivity to groundwater dependent ecosystems (GDE) (addressed in Section 6.4).

Information required under the IESC on Coal Seam Gas and Large Coal Mining Development was also requested under the DAWE RFI and is included in this Section, specifically:

- An overview of the project area geology, which includes lithostratigraphic details, structural geology (single fault), and maps
- A detailed description of the hydrostratigraphic units, transient potentiometric level data, flow patterns, and maps
    - including site-specific hydraulic properties including the Evergreen Formation (as per the DAWE RFI)

- Hydrochemical data, which allowed for the assessment of hydraulic interaction between hydrostratigraphic units and surface water
- The compilation of climate data, water balance information, and evaluation of recharge and discharge mechanisms
- The development of conceptual site models through evaluation of groundwater elevation data
  - numerical groundwater models were not required because no causal impact pathway was identified (i.e., no identifiable potential impact pathway that can be modelled)
- An evaluation of the existing recharge/discharge pathways of the hydrostratigraphic units
- A waterhole water balance, the compilation of discharge details, and a review of each potentially impacted (ground)water resource
- A cumulative impact assessment, where potential impacts of current and proposed groundwater extraction in the Surat Cumulative management Area (CMA) are considered
- An assessment and evaluation of significant impacts associated with the proposed water release activities.

On 04 August 2022, DCCEEW requested additional information following their review of the Preliminary Documentation (AECOM, 2022). Applicable elements relating to groundwater included:

- Shallow groundwater systems at the project site may be impacted by the releases of desalinated water
- Desalinated water releases, especially at low flows, are very likely to alter hyporheic water chemistry (assuming hyporheic water is chemically different from the released water) because of advective exchange in the riverbed in places where groundwater inputs are weak or absent, and this will potentially occur for a considerable distance downstream if the releases continue for years to decades.

An updated cross reference table against the IESC checklist is included in Appendix C-1.

4.1 Baseline groundwater description

4.1.1 Geology

4.1.1.1 Regional geology

The proposed action area overlies two geological basins, the Permian-Triassic Bowen Basin, and the Jurassic-Cretaceous Surat Basin. The Bowen Basin is an elongate north-south trending basin which covers approximately 160,000 km^2 of Queensland and New South Wales. The Surat Basin unconformably overlies the Bowen Basin and covers an area of approximately 440,000 km^2, extending from north of Taroom, Queensland to north of Dubbo, New South Wales. A summary of the stratigraphic units (and aquifer type) that form the Surat and Bowen basins are contained on Figure 4-1.

The proposed action area overlies outcropping basal units of the Surat Basin comprising the Evergreen Formation and Precipice Sandstone. Coal seams, targeted for CSG production adjacent to the proposed action area, are within the Bandanna Formation. The Bandanna Formation is an upper unit of the Bowen Basin. The Bowen Basin is unconformably overlain by basal sediments of the Surat Basin. Target coal seams of the Bandanna Formation in the proposed action area are hydraulically separated from basal units of the Surat Basin by the thick and laterally continuous Rewan Group aquitard (Figure 4-1). Above the Rewan Group and Moolayember Formation of the Bowen Basin, and above an unconformity lies the Bundamba Group within the Surat Basin consisting of the Precipice Sandstone, and Evergreen Formation containing the lower Evergreen Formation, Boxvale Sandstone, Upper Evergreen Formation, and Hutton Sandstone.

The Precipice Sandstone lies unconformably on the Bowen Basin sediments and is characterised by massive, porous quartzose sandstone (OGIA, 2016). The Precipice Sandstone, based on deposition, comprises both an upper and lower unit. The upper Precipice Sandstone is a fine to medium grained white to light grey highly friable sandstone with inter-bedded siltstone. The more extensive lower unit is white, fine to coarse grained porous quartzose sandstone, exhibiting some crossbedding (Jensen et al., 1964) and forms the primary aquifer for this unit.

The Evergreen Formation comprises labile and sub-labile, sandstone overlain by carbonaceous mudstone, siltstone, and minor coal with local oolitic ironstone[13]. The Evergreen Formation contains the Boxvale Sandstone, which effectively subdivides the formation into three main units: the upper and lower Evergreen formations and the Boxvale Sandstone (OGIA, 2019). The Evergreen Formation contains the Westgrove Ironstone member in places. The Evergreen Formation is a low permeability portion of the aquitard unit, that confines the Precipice Sandstone.

The Boxvale Sandstone Member comprises fine to coarse grained, cross bedded, quartzose sandstone with carbonaceous siltstone, shale, and coal interbeds.

4.1.1.2 Structural geology

Adjacent to the proposed action area, there are regional fault systems within the Bowen and Surat Basins. However, these are generally within the deeper Bowen Basin sediments and have reduced displacement effects in the overlying, younger Surat Basin formations (QWC, 2012).

The proposed action area is located east of the axis of the Arcadia Anticline (mapped as a fold on Figure 4-2). The anticline shows a north-west to south-east orientation through the area. To the north-east, the Triassic Bowen Basin sediments are exposed at the surface forming the Arcadia Valley with the anticline dipping to the south-east (KCB, 2012b). Smaller faults and fractures may be associated with this anticline, however, only the main north-west to south-east strike fault is mapped in this area (Figure 4-2) as it is structurally large and pervasive. This fault is mapped 2 km to the south of the desalinated water release point.

The fault, albeit adjacent to the proposed action area, is not relevant to the hydrogeological conceptual model at the proposed action area because it is located far from the proposed release activities and does not directly affect the geology or hydrogeology at the site.

4.1.1.3 Geology within the proposed action area

Within the broader region of the proposed action the Dawson River has incised into the basal Jurassic sediments of the Surat Basin, resulting in a landscape characterised by plateaus formed by the Boxvale Sandstone and valleys of exposed Evergreen Formation and Precipice Sandstone.

Within the proposed action area, the Dawson River contains thin transient and highly mobile alluvial deposits for the entire length of the river in the proposed action area. These sediments are highly mobile under the seasonal flow regime described in Section 5.2.2. The location of pools runs, and riffles within Dawson River alluvial sediments change morphology during each high flow event.

The desalinated water release point and drainage feature are underlain by Hutton Sandstone, Boxvale Sandstone and Westgrove Ironstone Member that are in turn underlain by the lower Evergreen Formation adjacent the waterhole (Figure 4-2). The waterhole and watercourse, which connects the waterhole to the main Dawson River channel (Figure 4-3), is underlain by thin alluvial (and colluvial) deposits that are located on the Evergreen Formation.

Downstream of the watercourse confluence, the Evergreen Formation underlies the Dawson River for some 4.3 km, before the river crosses the younger Boxvale Sandstone and Westgrove Ironstone members of the Evergreen Formation near the downstream limit of the proposed action area (Figure 4-2).

[13] Australian Stratigraphic Units Database (https://asud.ga.gov.au/search-stratigraphic-units/)

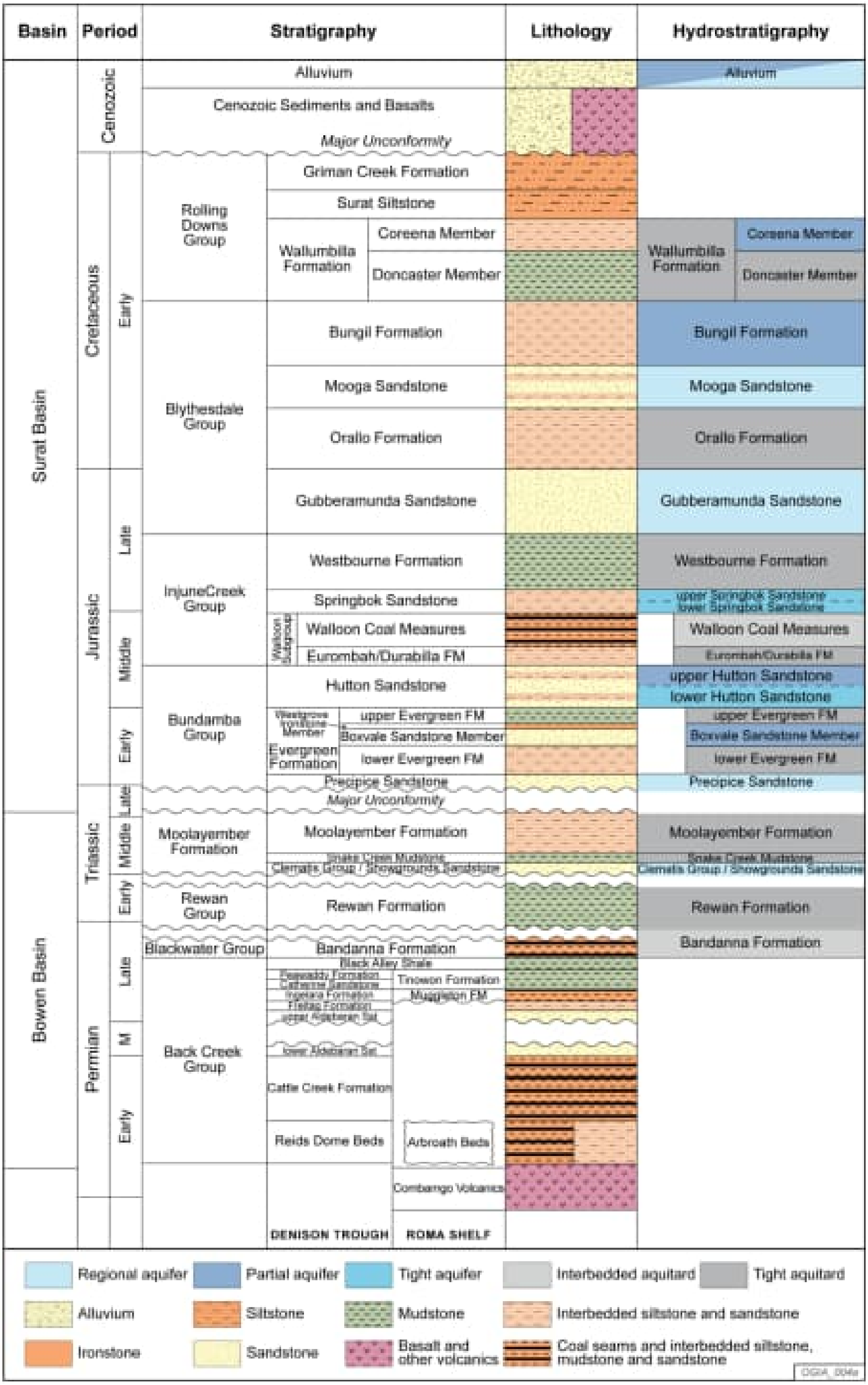


Figure 4-1 Generalised hydrostratigraphic units in the Surat CMA (OGIA, 2021)

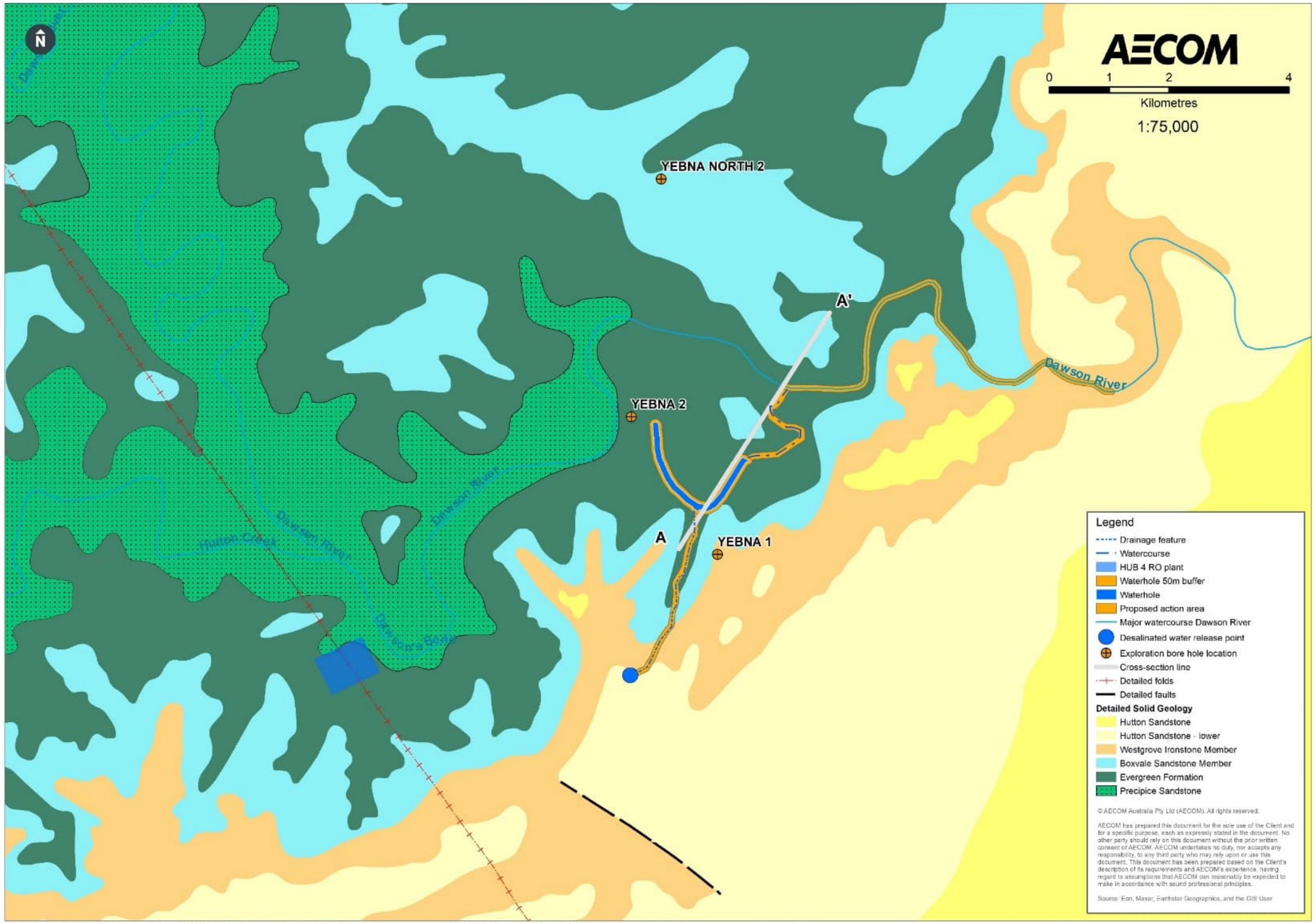


Figure 4-2 Proposed action area geology

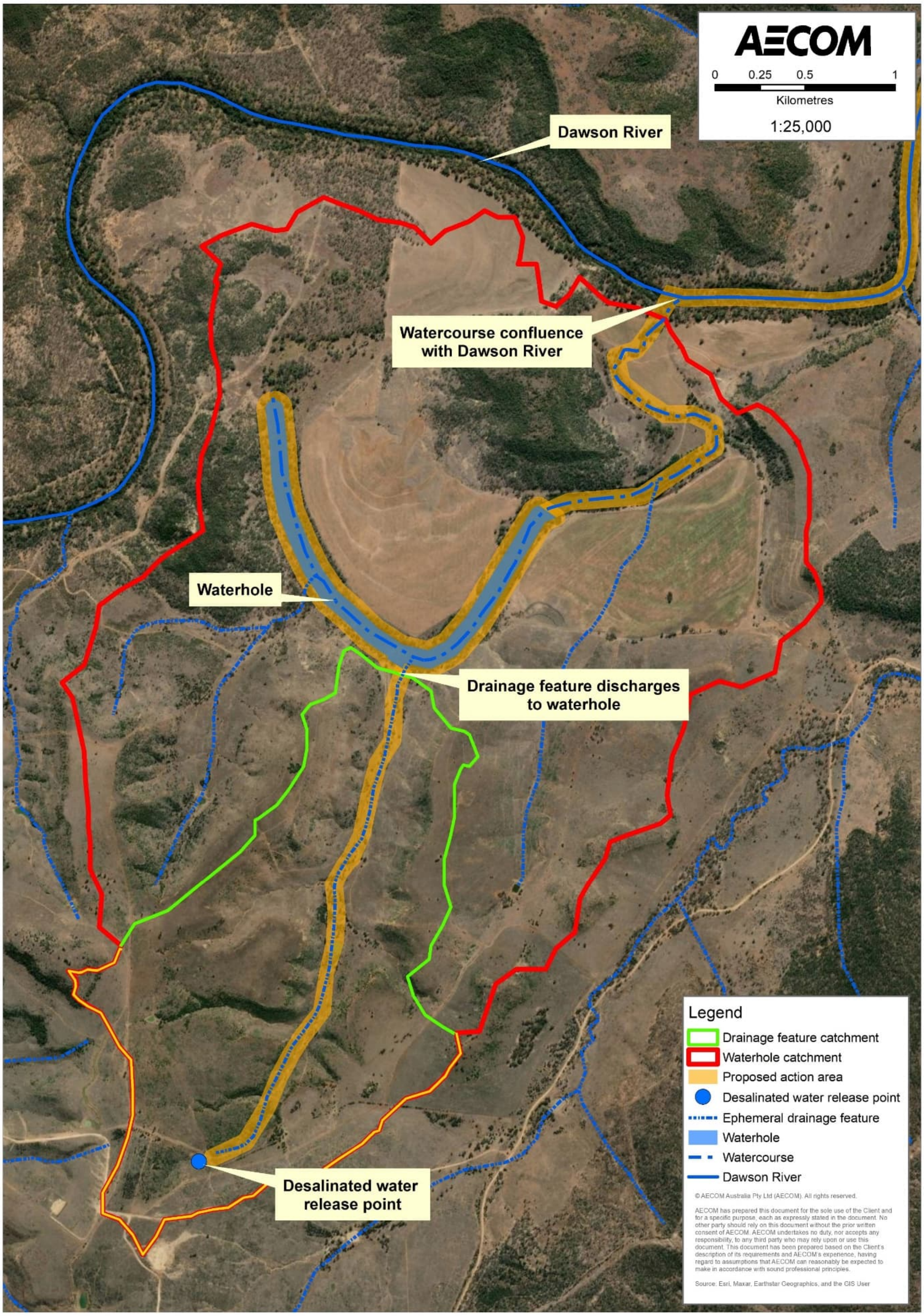


Figure 4-3 Waterhole catchment area (Source: after Alluvium, 2012)

4.1.1.4 Alluvium

Regional scale mapping presented on QGlobe[14] (surface geology layers) does not map alluvium upstream or within the proposed action area (OGIA, 2021). However, some alluvium below the regional scale mapping resolution is present as discussed below.

Dawson River alluvium

Fluvial transport of alluvium was recognised within the proposed action area where the Dawson River channel can contain in-stream alluvial sand interspersed with sub angular boulders of siltstone during lower flow periods. Higher flows mobilise these (temporary) in-stream alluvial sand deposits. The unconsolidated in-stream alluvial material overlies sandstone and siltstone bedrock of the Precipice Sandstone and Evergreen Formation respectively where present. The riverbanks consist of bedrock outcrops and minor sandy alluvium.

The Dawson River in-stream alluvium is regularly flushed downstream during high flow events. Based on the transient nature of the unconsolidated material, limited thickness, continuity (bedrock outcrop), and fine particle size, the in-stream alluvium deposits are not considered a consistent aquifer.

Within the proposed action area, historical investigations of groundwater fed spring complexes have been conducted. The Wetland Conceptualisation report for the 311 and Yebna 2 spring complexes (OGIA, 2015) along with hydrogeological reports for other spring complexes located along the reaches of the Dawson River, concluded:

- *"The spring associated wetlands have little or no regolith and, therefore, no effective storage capacity"*

This supports the description of the alluvial deposits associated with the Dawson River as poorly developed, discontinuous, and transient. Figure 4-13 and Figure 6-2 (in Section 6.2) provides locations of springs located within the proposed action area.

Waterhole colluvium and alluvium

The HCS04 ROP is elevated about 25 m above the Dawson River. The desalinated water release pipe is some 100 m above the Dawson River at the head of a drainage feature, approximately 5 km east of the HCS04 ROP. These areas are mapped as bedrock underlying thin soil. No alluvial material is mapped within the drainage feature receiving released desalinated water.

Hill wash sediments, mobilised within surface water flows within the 14.9 km^2 catchment (Figure 4-3), are expected within the waterhole. Backflow from the Dawson River under high flood levels (Section 4.2.3.3) could also intermittently deposit sediment under flood conditions when the river flow level is higher than the waterhole outlet level (Figure 4-3). Historical alluvium is also expected below the waterhole, based on historic hydraulic connection with the Dawson River as river sediment prior to the channel being cut off to form the waterhole as an oxbow lake.

4.1.1.5 Evergreen Formation

The Evergreen Formation conformably overlies the Precipice Sandstone and is in turn overlain by the Hutton Sandstone (Figure 4-1).

The Evergreen Formation is up to 400 m thick within areas of maximum deposition (depocentres) but averages a thickness of 125 m (OGIA 2016; Ransley et.al 2014). The Boxvale Sandstone, where present, varies in thickness up to nearly 60 m, but averages around 15 m.

Evergreen Formation thickness within the proposed action area

Bore logs from three Santos exploration bores; Yebna 1, Yebna 2, and FV13-30-1, located adjacent to the proposed action area and intersect the Evergreen Formation, were reviewed (Figure 4-4). These bore logs were evaluated to assess the thickness of the Evergreen Formation in the proposed action area.

Table 4-1 provides a summary of the lithology intersected within these bores and the thickness.

[14] Queensland Globe - https://qldglobe.information.qld.gov.au/

Table 4-1 Stratigraphic thicknesses recorded in Santos exploration bores adjacent to the waterhole

Bore name	Yebna 1	Yebna 2	FV13-30-1
Surficial sediments	0 to 4 mbgl[15]	0 to 4 mbgl	0 to 4.32 mbgl
Hutton Sandstone			4.32 to 52.78 mbgl (48.46 m thick)
Evergreen Formation	4 to 134 mbgl (130 m thick)	4 to 59.12 mbgl (55.12 m thick)	52.78 to 167.05 mbgl (114.27 m thick)
Precipice Sandstone	134 to 210 mbgl (76 m thick)	59.12 to 111.44 mbgl (52.32 m thick)	167.05 to 219.07 mbgl (52.02 m thick)
Moolayember Formation	210 to 312 mbgl (102 m thick)	111.44 to 306.47 mbgl (195.03 m thick)	219.07 to 304.51 mbgl (85.44 m thick)

Evergreen Formation dip within the proposed action area

The depth to the lithology contacts in metres Australian Height Datum (m AHD) show the dip in the stratigraphy and the thickness of the Evergreen Formation above the Precipice Sandstone and adjacent to the waterhole.

Table 4-2 presents the lithological contacts and Figure 4-4 indicates the elevation of the base of the Evergreen Formation. The elevation of the base of the waterhole is ~245 m AHD as discussed in Section 4.2.3.1.

Table 4-2 Stratigraphic elevations recorded in Santos exploration bores adjacent to the waterhole

Bore name	Yebna 1	Yebna 2	FV13-30-1
Surface elevation	320.82 m AHD	282.5 m AHD	360 m AHD
Surficial sediments - base	316.82 m AHD	278.5 m AHD	355.68 m AHD
Hutton Sandstone - base	-		307.22 m AHD
Evergreen Formation – contact with Precipice Sandstone	186.82 m AHD	223.38 m AHD	192.95 m AHD
Precipice Sandstone - base	110.82 m AHD	171.06 m AHD	140.93 m AHD
Moolayember Formation - base	8.82 m AHD	-23.97 m AHD	55.49 m AHD

The bore log data, assessed to evaluate the waterhole, shows that the Evergreen Formation aquitard has a minimum thickness of at least 35 m below the waterhole (the base of the waterhole was surveyed when dry [Alluvium, 2012] (Figure 4-4).

This is the minimum thickness that separates the base of the waterhole and the Precipice Sandstone.

Generally, the thickness of the Evergreen Formation aquitard increases in thickness toward the southeast where it has a maximum thickness of approximately 55 m below the base of the waterhole (Figure 4-4).

4.1.1.6 Precipice Sandstone

The Precipice Sandstone comprises both an upper and lower unit within the proposed action area. The upper Precipice Sandstone is a fine to medium grained white to light grey highly friable sandstone with inter-bedded siltstone. The lower Precipice Sandstone comprises white, fine to coarse grained porous quartzose sandstone, with enhanced groundwater potential (the main aquifer).

[15] metres below ground level

The Precipice Sandstone lies unconformably on the Bowen Basin sediments and pre-Jurassic basement and is conformably overlain by the Evergreen Formation. The Precipice Sandstone is a major regional aquifer and acts as a source of groundwater for industrial, agricultural, and domestic purposes within and proximal to the proposed action area.

Regionally, the formation is up to 110 m thick in the northeast and northwest. The unit thins, and the base gets younger to the west, such that the Precipice Sandstone is not present in some parts of the Surat Basin, and the Evergreen Formation sits unconformably on Bowen Basin strata or pre-Permian basement (Ransley et.al 2014).

Within the proposed action area and based on the data recorded in the Santos exploration bore logs (summarised in Table 4-1 and Table 4-2), the thickness of the Precipice Sandstone ranges from around 50 m to 80 m.

4.1.1.7 Permian coal

The Bandanna Formation is the main productive Permian CSG formation within the Bowen Basin. This unit is targeted within the proposed action area for CSG.

The Bandanna Formation is generally well isolated from productive aquifers within the proposed action area. The underlying Permian formations have little permeability and the low-permeability mudstones of the Rewan Group separate the formation from overlying aquifers. It is therefore unlikely that depressurisation of the Bandanna Formation will affect surrounding aquifers.

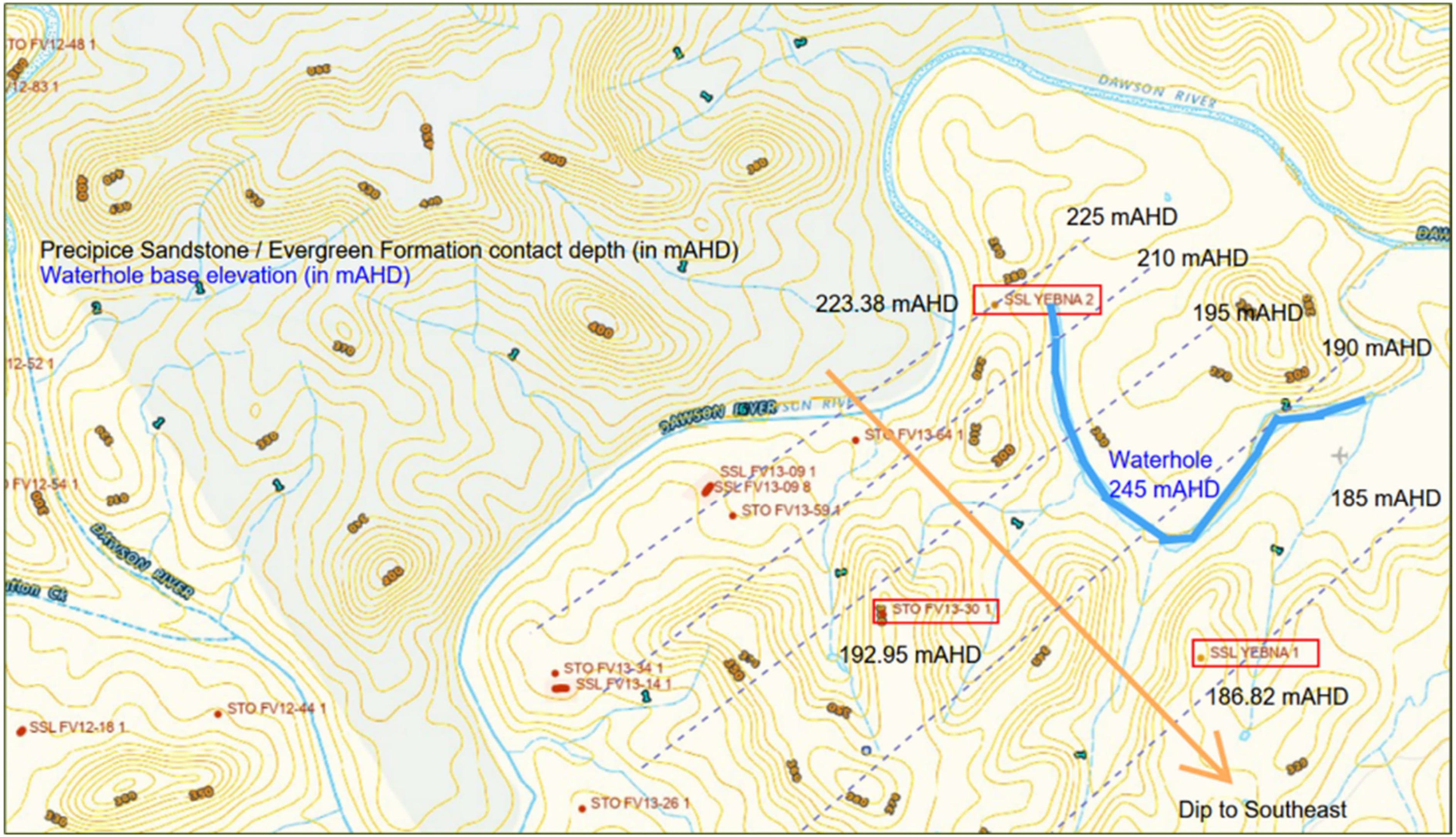


Figure 4-4 Elevation of the base of the Evergreen Formation adjacent to the waterhole

4.1.2 Hydrogeology

The proposed action area is located within sedimentary units that form the basal part of the Great Artesian Basin (GAB). The Precipice Sandstone is a major GAB aquifer, present within the proposed action area.

The Precipice Sandstone is an important and high value groundwater source adjacent and below the proposed action area. It provides perennial spring flow and baseflow to the Dawson River in the location adjacent to the HCS04 ROP and 9 km downstream of the waterhole (Figure 4-2), where the Dawson River has incised into the Precipice Sandstone. It is also the source aquifer for groundwater users (water bores) in proximity to the proposed action area.

Locally, the Boxvale Sandstone Member of the Evergreen Formation forms an inselberg (outlier) in the landscape, which is discontinuous because of landscape evolution and erosional processes. As a result, groundwater is not encountered in the Boxvale Sandstone within the proposed action area.

4.1.2.1 Evergreen Formation hydrogeology

Hydraulic properties

The Evergreen Formation is a major regional aquitard between two regionally significant aquifers:

- The overlying Hutton Sandstone
- The underlying Precipice Sandstone.

Within the proposed action area, the Evergreen Formation is an aquitard and confining bed of the Precipice Sandstone.

Analysis of the available core, drill stem tests (DST), petrophysical, and pumping test data has been compiled to provide an estimate of the hydraulic properties of the Evergreen Formation (Table 4-3 and Table 4-4). The data indicates that the formation has median horizontal hydraulic conductivity ranging from 0.25 to 810 millidarcy (mD)[16] (around 0.0003 to 1.03 m per day) (OGIA, 2016).

Values derived only from pumping tests are about two orders of magnitude higher than the lowest measurement from the whole dataset. This is likely attributable to pumping tests only being carried out on the Boxvale Sandstone member rather than the low-permeability Evergreen Formation. As such, the values derived from pumping tests are considered representative of the Boxvale Sandstone member only.

Petrophysical data indicate the lowest median horizontal permeabilities of 0.006 mD (7.62×10^{-05} m per day). This is interpreted to be the result of sample bias towards some very low permeability clay layers (OGIA, 2016). The median effective porosity from petrophysics is 0.05 per cent, which is the lowest out of all the Surat Basin units (OGIA, 2016).

Available aquifer hydraulic properties, from both the Evergreen Formation and Boxvale Sandstone, was included in the Underground Water Impact Report (UWIR) groundwater modelling report (OGIA, 2019). These data are included in Table 4-4 and Table 4-5 for the Evergreen Formation and the Boxvale Sandstone, respectively. These data are based on additional drilling and aquifer assessments and are deemed more representative of the Evergreen Formation aquitard compared to the 2016 assessment.

[16] 1 millidarcy (mD) = 1.27×10^{-03} m/day

Table 4-3 Evergreen Formation (inclusive of the Boxvale Sandstone) hydraulic properties (OGIA, 2016)

Data	Core			DSTs			Pumping tests		
	10th percentile	Median	90th percentile	10th percentile	Median	90th percentile	10th percentile	Median	90th percentile
Horizontal hydraulic conductivity (Kh) (m/day)	1.42×10^{-03}	2.54×10^{-01}	$5.88 \times 10^{+01}$	1.25×10^{-01}	$7.20 \times 10^{+00}$	$3.23 \times 10^{+02}$	$1.34 \times 10^{+02}$	$8.10 \times 10^{+02}$	$8.09 \times 10^{+03}$
Vertical hydraulic conductivity (Kv) (m/day)	6.54×10^{-04}	6.69×10^{-02}	$3.53 \times 10^{+01}$	5.14×10^{-02}	$2.35 \times 10^{+00}$	$1.65 \times 10^{+02}$	-	-	-

- No data

Table 4-4 Lower Evergreen Formation hydraulic properties (OGIA, 2019)

Data	Minimum (m/day)	Maximum (m/day)	Median (m/day)
Pre-calibrated horizontal hydraulic conductivity (K_h)	1.58×10^{-05}	2.53×10^{-04}	6.09×10^{-05}
Calibrated horizontal hydraulic conductivity (Kh)	1.58×10^{-05}	2.53×10^{-04}	6.27×10^{-05}
Pre-calibrated vertical hydraulic conductivity (Kv)	5.08×10^{-09}	2.27×10^{-04}	1.64×10^{-08}
Calibrated vertical hydraulic conductivity (Kv)	5.08×10^{-09}	9.77×10^{-05}	1.73×10^{-08}

Table 4-5 Boxvale Sandstone hydraulic properties (OGIA, 2019)

Data	Minimum (m/day)	Maximum (m/day)	Median (m/day)
Pre-calibrated horizontal hydraulic conductivity (K_h)	1.03×10^{-04}	2.51×10^{-03}	3.32×10^{-04}
Calibrated horizontal hydraulic conductivity (Kh)	9.65×10^{-05}	3.14×10^{-01}	3.11×10^{-04}
Pre-calibrated vertical hydraulic conductivity (Kv)	3.11×10^{-08}	2.27×10^{-04}	8.29×10^{-08}
Calibrated vertical hydraulic conductivity (Kv)	3.11×10^{-08}	1.68×10^{-04}	7.62×10^{-08}

Table 4-6 Effective porosity ranges for the Evergreen Formation (inclusive of the Boxvale Sandstone) based on petrophysical data (OGIA, 2016)

	Effective porosity (%)	Total porosity (%)
10^{th} percentile	1	14
Median	5	19
90^{th} percentile	14	28

Table 4-7 Evergreen Formation key groundwater quality parameters (OGIA, 2016)

Number of samples	Mean Concentrations (mg/L)									
	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Bicarbonate	Total Dissolved Solids	pH	SAR
42	22	9	61	4	59	11	167	263	7.5	4

Hydrochemistry

Table 4-8 provides the key water quality parameters of the Evergreen Formation / Boxvale Sandstone derived from the 2016 water quality dataset (OGIA, 2016).

This data indicates the Evergreen Formation is characterised by low salinity (total dissolved solids [TDS]). However, it is likely that most samples were obtained from the Boxvale Sandstone Member, as opposed to the low permeability Evergreen Formation. In general, TDS ranges from 80 to 670 mg/L, with a mean TDS of 260 mg/L.

No groundwater quality monitoring data is available for the Evergreen Formation aquitard (low permeability material).

Local Evergreen Formation hydrochemistry

Three groundwater samples from bores that intersect the Evergreen Formation were identified from the available registered bore cards (DOR, 2021). The water quality from these bores, RN16785, RN58062, and RN58362, plus bores logged to intersect the Boxvale Sandstone Member is included in Table 4-8.

Table 4-8 Evergreen Formation groundwater quality parameters (DOR GWDB, 2021)

Registered Bores (date)	Concentrations (mg/L)									
	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Bicarbonate	Fluoride	pH	TDS
Evergreen Formation										
RN16785 (11/1975)	40	15	62	2	135	17	140	0.13	7.6	340
RN58062 (03/1982)	28	5	110	1	130	26	162.2	0	8.1	379
RN58362 (09/1996)	3.3	1.5	22	2.7	15	0	57.3	0.01	6.4	73
Boxvale Sandstone Member										
RN58420 (07/1993)	13.2	0.5	324	0.6	172	32.4	546.2	0.02	8.3	811
RN58428 (07/1993)	5.3	3.3	23	1.7	20	0	61	0.02	6.5	83
RN58441 (08/1993)	7.6	5.8	23	2	15	0	87.8	0.13	7.4	96

The hydrochemistry included in Table 4-8 is highly variable indicating poor hydraulic connectivity across differing members within the Evergreen Formation, as indicated in the Piper Plot (Figure 4-5). The water type is Na – Cl + HCO_3, as indicated in the Schoeller diagram (Figure 4-6).

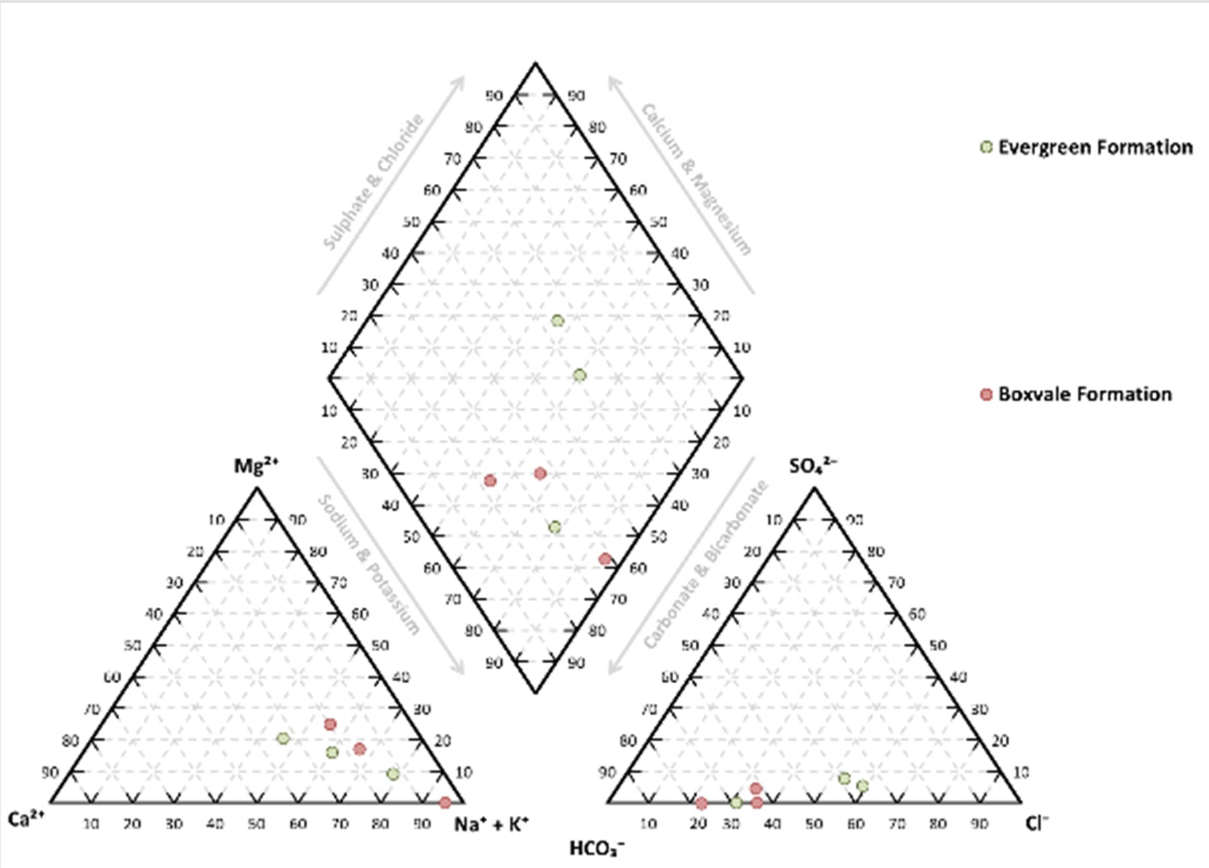


Figure 4-5 Evergreen Formation data from local registered bores – Piper Plot

Figure 4-6 Evergreen Formation data from local registered bores – Schoeller Diagram

Groundwater recharge

The long-term average recharge estimate for the Evergreen Formation is 7.3 mm/year. This is comparatively high, as most samples are representative of the Boxvale Sandstone Member of the Evergreen Formation; this estimate is therefore not representative of the Evergreen Formation.

Groundwater yields

The mean groundwater yield for the Evergreen Formation is 2.1 L/s with a range of <1 to 13 L/s. These yield measurements are likely to be representative of the Boxvale Sandstone, rather than the Evergreen Formation aquitard.

Groundwater levels and flow directions

Regional groundwater elevations in the Evergreen Formation (including the Boxvale Sandstone member) range from 700 m AHD in the northwestern outcrop, decreasing to 200 m AHD to the southwest towards the Dawson River.

The pattern of groundwater flow in the Evergreen Formation is predominantly to the south from the interpreted groundwater divide at the Great Dividing Range. The contours suggest that the influence of the groundwater divide appears to be less prominent in the Evergreen Formation compared to overlying aquifers.

Groundwater discharge from the Evergreen Formation in the southeast outcrop is likely due to an abrupt change in topography to the west of Toowoomba, sufficient to override the subtle dip of the formation over the Helidon Ridge.

Vertical gradients

An assessment of groundwater levels in the Evergreen Formation bores compared to the Precipice Sandstone, allowing for the evaluation of vertical gradients and (no) hydraulic connectivity, is included in Section 4.2.1.1.

Natural groundwater discharge

Groundwater discharge from the Boxvale Sandstone member of the Evergreen Formation to surface water systems occurs in isolated areas along the northern outcrop of the unit within the Surat Basin, but not recognised in the proposed action area. In addition to diffuse areas of discharge, several spring complexes are thought to receive groundwater flow from the confined areas of the Boxvale Sandstone member. Groundwater from the confined Boxvale Sandstone member discharges to surface along fractures to form these springs.

Groundwater discharge from the Evergreen Formation is not recognised within the waterhole in the proposed action area due to deep groundwater levels and limited aquifer parameters, discussed further in Section 4.2.1.1.

The Boxvale Sandstone is mapped within the waterhole area, between the waterhole and the Dawson River (Figure 4-2, State of Queensland, 2021). The Boxvale Sandstone is mapped as an outlier, corresponding to the small hill, that is disconnected from the regional unit (as detailed in Section 4.1.2). As such, the recharge and effective storage of this outlier is considered too low to allow significant groundwater discharge to the waterhole.

4.1.2.2 Precipice Sandstone groundwater

Analysis of the available core, DST, petrophysical and pump test data was compiled in 2016 to provide a range of the hydraulic properties for the Precipice Sandstone. This data is included in Table 4-9 to Table 4-11.

The data show the Precipice Sandstone is a regionally pervasive and highly productive aquifer. The aquifer hydraulic properties of the Precipice Sandstone show less variability and are more permeable than any other Surat Basin formation.

Spatially, higher permeabilities within the Precipice Sandstone occur in or near the outcrop areas. The aquifer hydraulic parameters included in the groundwater model (OGIA, 2019) are included in Table 4-10.

Table 4-9 Precipice Sandstone hydraulic properties (OGIA, 2016)

Data	Core			DSTs			Pump tests		
	10th percentile	Median	90th percentile	10th percentile	Median	90th percentile	10th percentile	Median	90th percentile
Horizontal hydraulic conductivity (Kh) (m/day)	4.00E-02	1.34E+01	5.42E+02	3.67E-01	1.57E+01	7.00E+02	4.18E+02	2.35E+03	7.36E-03
Vertical hydraulic conductivity (Kv) (m/day)	8.71E-03	6.53E+00	1.05E+03	2.20E-01	7.34E+00	4.16E+02	-	-	-

- No data

Table 4-10 Precipice Sandstone hydraulic properties (OGIA, 2019)

Data	Minimum (m/day)	Maximum (m/day)	Median (m/day)
Pre-calibrated horizontal hydraulic conductivity (K_h)	2.60E-02	1.97E+01	5.07E-01
Calibrated horizontal hydraulic conductivity (Kh)	1.04E-02	1.00E_02	7.47E-01
Pre-calibrated vertical hydraulic conductivity (Kv)	4.99E-06	1.46E-03	4.57E-04
Calibrated vertical hydraulic conductivity (Kv)	1.84E-06	1.73E-03	5.70E-04

Table 4-11 Effective porosity ranges for the Precipice Sandstone based on petrophysical data (OGIA, 2016)

	Effective porosity (%)	Total porosity (%)
10^{th} percentile	5	15
Median	16	22
90^{th} percentile	26	28

Hydrochemistry

The median values for key groundwater quality parameters in the Precipice Sandstone are included in Table 4-12.

Table 4-12 Precipice Sandstone key groundwater quality parameters (OGIA, 2021)

Number of samples	Mean Concentrations (mg/L)									
	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Bicarbonate	TDS	pH	SAR
662	3	1	47	2.1	15	1	125	184	7.5	8

Groundwater samples from registered bores adjacent to the proposed action area, constructed to intersect the Precipice Sandstone include RN160771, RN160779, and RN160780. These bores are included in Section 4.2.

A summary of the Precipice Sandstone hydrochemistry is included in Table 4-13.

Table 4-13 Precipice Sandstone groundwater quality parameters (DOR GWDB, 2021)

Registered Bores (date)	Concentrations (mg/L)									
	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Bicarbonate	Fluoride	pH	TDS
RN160771 (03/2015)	6	2	22	2	15	1	79.93	0.1	6	341
RN160771 (05/2014)	6	2	23	3	16	1	79.93	0.1	6.1	320
RN160779 (05/2021)	8	5	23	2	16	1	84.17	0.1	6	322
RN160780 (05/2019)	18	10	21	2	12	1	141.51	0.1	6	490

The Precipice Sandstone groundwater quality is typical of inert silica-rich (quartzite) sandstone with acidic pH (from rainfall) and limited major anions and cations. The water type is Na – HCO_3 dominant as illustrated in the Schoeller diagram (Figure 4-7).

The Piper Plot (Figure 4-8) for the Precipice Sandstone water quality results in Table 4-13 indicate fresh to mixing, possibly related to distance of bores (spatially and with depth) from the recharge areas.

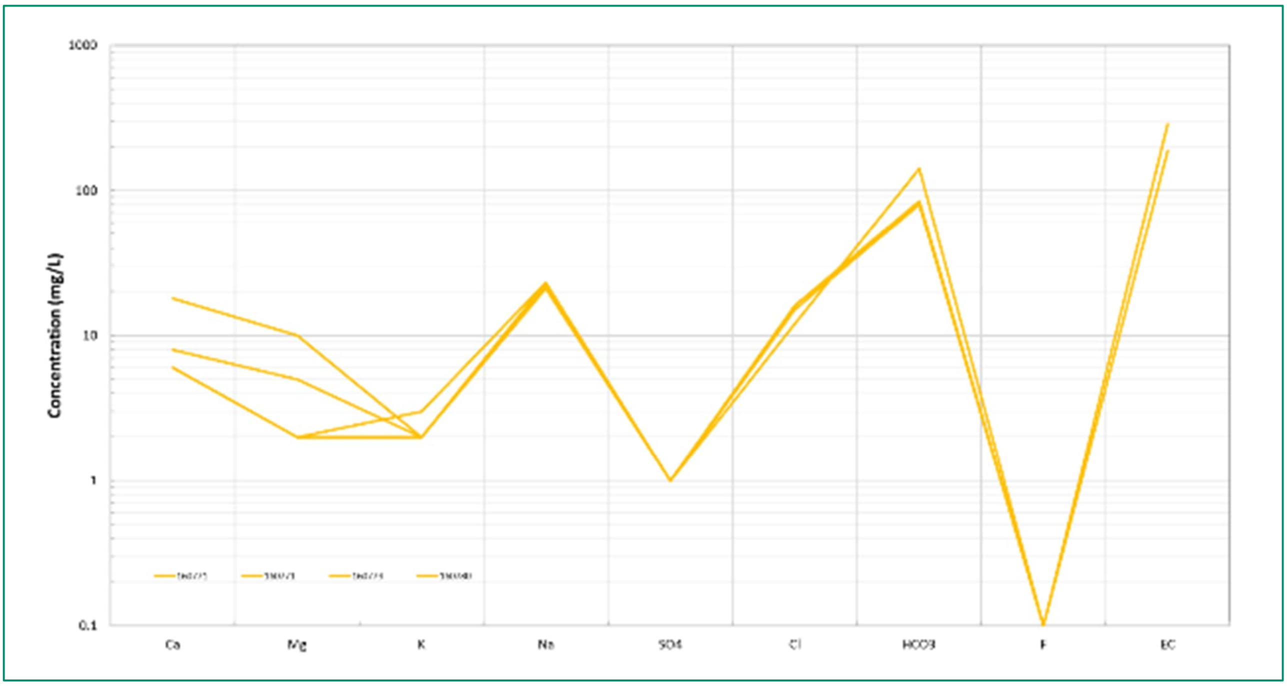


Figure 4-7 Precipice Sandstone data from local registered bores – Schoeller Diagram

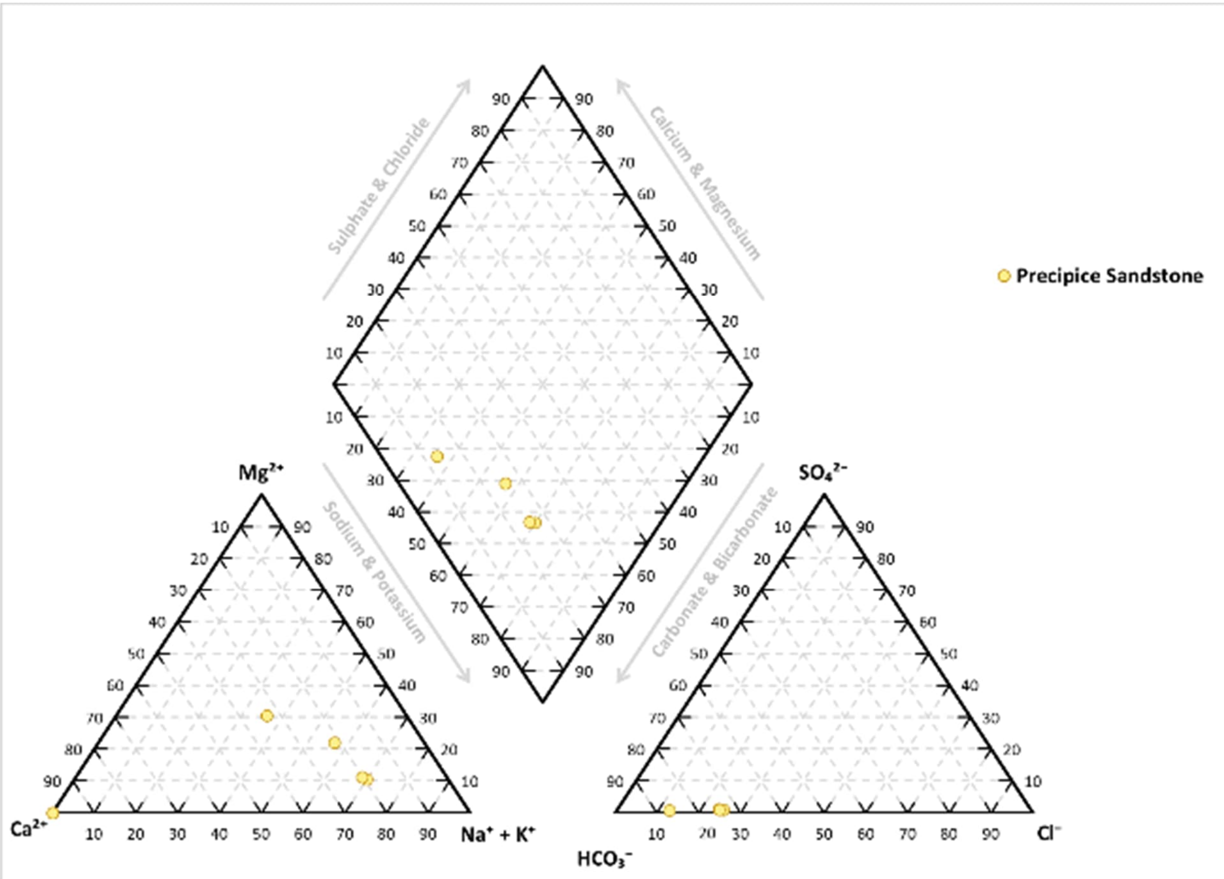


Figure 4-8 Precipice Sandstone data from local registered bores – Piper Plot

Groundwater recharge

Estimates of long-term recharge for the Precipice Sandstone is estimated at 20.8 mm/year (OGIA, 2019). Compared to other formations, this is very high, but is consistent with other hydrogeological characteristics of the Precipice Sandstone including the relatively high estimated storage properties, permeability, and transmissivity.

Groundwater yields

Water quality for the Precipice Sandstone is considered suitable for most purposes; however, despite this, the total estimated use from the aquifer is only about 6,125 ML per year (OGIA, 2019). The moderate level of groundwater extraction from this formation is thought to reflect the relatively poor accessibility to the aquifer (depth); in many areas of groundwater use the Precipice Sandstone is overlain by other productive aquifers which represent more cost-effective targets due to their shallower depth (OGIA, 2016).

Groundwater levels and flow directions

Interpolated regional groundwater level contours for the Precipice Sandstone are shown on Figure 4-9. Groundwater elevations range from 700 m AHD in outcrop areas towards the northwest, to 220 m AHD to the northeast, near Taroom, an area of known groundwater discharge.

In the aquifer outcrop and in adjacent areas, there is evidence of a correlation between groundwater pressure, rainfall patterns and likely recharge events. Further from outcrop areas, where the Precipice Sandstone is increasingly confined, there is reduced correlation with rainfall patterns and generally stable to slightly decreasing groundwater levels.

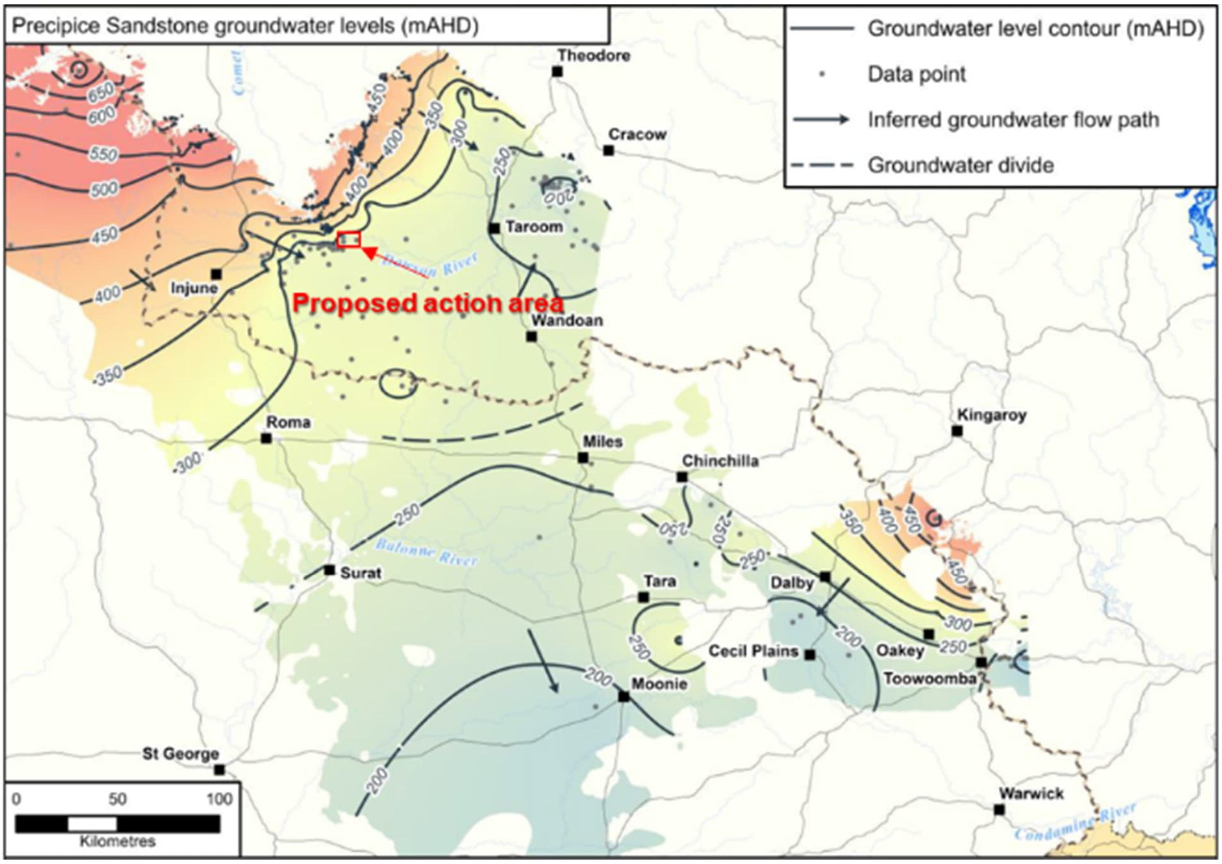


Figure 4-9 Groundwater flow patterns in the Precipice Sandstone (OGIA, 2019)

Although the overarching groundwater level trend is stable, in the Precipice Sandstone, there are short-term water level responses to reinjection.

Origin has established injection facilities at the Spring Gully and Reedy Creek gas fields where it has been reinjecting treated CSG water since 2015 (OGIA, 2021). This has led to a slight increase of around one metre in groundwater pressures in the Precipice Sandstone within the proposed action area.

Local groundwater flow patterns

Jacobs (2019) compiled and contoured the available Precipice Sandstone potentiometric groundwater level data within the proposed action area. These contours and groundwater flow patterns were included in the Lower Hutton Creek and Upper Dawson River Hydrogeological Conceptualisation (Jacobs, 2019).

The Dawson River is underlain by Precipice Sandstone west of the waterhole (Figure 4-2). This is a regionally significant aquifer discharge zone. Where the Dawson River has incised the Evergreen Formation and exposes the Precipice Sandstone, it receives baseflow directly from the Precipice Sandstone. Across this section of the Dawson River, approximately 25 km in length, the Precipice Sandstone discharges in excess of 250 L/s (~8 GL/year).

It is noted in Figure 4-10 that the increase in flow evident between DR11 and DR12 in 2017 (and DR11 to DR14 in 2018) is due to the inflow from the waterhole discharge location, downstream of DRR1. This reach is located within the Evergreen Formation and the observed slight increase in flow is not from the Precipice Sandstone discharge but waterhole discharge.

The generated potentiometric surface contours **(**Figure 4-11) and observed discharge, indicate:

- The local groundwater flow in the Precipice Sandstone at the proposed action area influences regional groundwater gradients flow due to discharge into the Dawson River.
- The Evergreen Formation aquitard fully confines the Precipice Sandstone.
- The steep hydraulic gradients and confined nature of the Precipice Sandstone results in a potentiometric surface within the Precipice Sandstone. This potentiometric surface is above ground elevation, particularly for the area of waterhole, which is low in the landscape at a ground elevation of 250 m AHD.

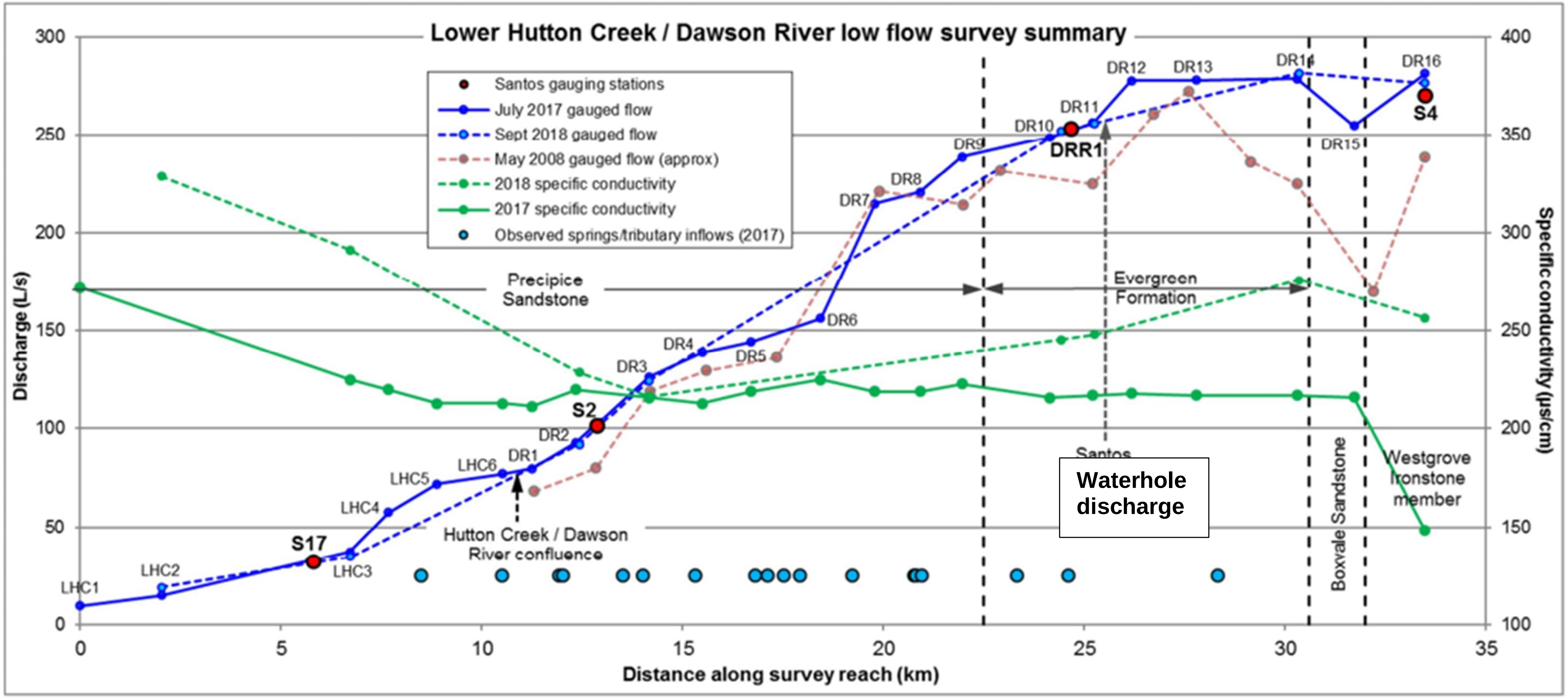


Figure 4-10 **Santos gauging data along the Dawson River adjacent to the proposed action area (source: Jacobs, 2019)**

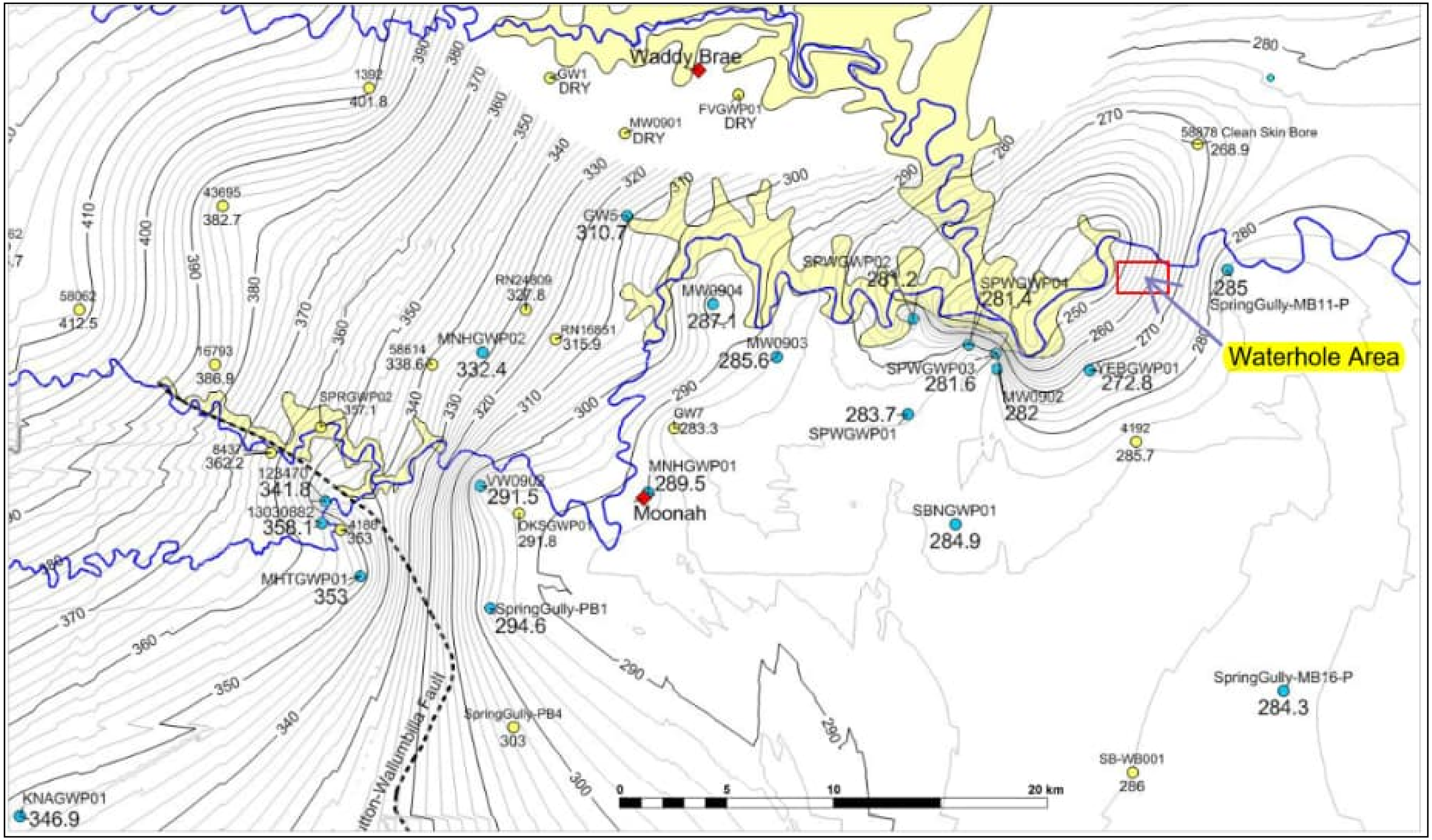


Figure 4-11 Potentiometric surface map for the Precipice Sandstone [December 2014 - pre-injection] (source: Jacobs, 2019)

4.1.2.3 Precipice Sandstone springs

History of spring investigations

A long history of springs, groundwater discharge, and/or wetland investigations and classification studies have been conducted within the Surat CMA including the proposed action area. These studies include:

- A survey of all springs within project areas and 100 km of CSG project areas for the presence or absence of EPBC Act 1999 listed species.
- The OGIA's spring research program, which commenced in 2012 and has involved several desktop studies and detailed site investigations, which facilitated an improved understanding of the hydrological regime of the springs and linkages with ecology.
- Data collected from field investigations by OGIA and the CSG industry during the implementation of dedicated monitoring and investigation program under the requirement of the Surat UWIR (2012) and in accordance with Commonwealth monitoring obligations.
- For the Surat UWIR (2012), preliminary site investigations were conducted in 2012 by Fensham et al. (2012) and KCB (2012b). Wetlands in the Surat CMA that were listed in the Queensland Herbarium Springs database were visited, ecological surveys were conducted (Fensham et al., 2012) to support preliminary hydrogeological and hydrogeochemical characterisations (KCB, 2012b).
- Geological data and interpretation by OGIA and the CSG industry sourced via the Queensland Petroleum Exploration Database (QPED). The Bowen and Surat Regional Structural Framework Study (SRK, 2008) and the 1:250 000 geological mapping produced by the Geological Survey of Queensland (GSQ).
- Groundwater data from the Department of Resources (DOR) Groundwater Database (GWDB) and baseline assessment data collected by the CSG industry.
- A range of spatial datasets including infrastructure, land system mapping, imagery, and meteorological information.
- Wolhuter, et al (2013) prepared Hydrogeology of Great Artesian Basin Springs and Fensham, et al. (2015) prepared a report an ecological and hydrogeological survey of the Great Artesian Basin springs – Springsure, Eulo, Bourke, and Bogan River supergroups.

These studies allowed for the identification of all groundwater dependent spring complexes and wetlands[17] within the Surat CMA (Figure 4-12).

These groundwater discharge investigations, undertaken at the landscape and site-specific scale, did not identify any additional groundwater discharge features in landscape relating to the waterhole. This is a robust finding given the volume of site-specific investigation that has occurred in the proposed action area since 2012.

[17] Spring fed wetlands, which are ecosystems that are reliant on the surface expression of groundwater, are referred to as springs, spring wetlands, or water course springs. These are all described as gaining wetlands. The term 'wetlands' is used to include springs and water course springs. A cluster of wetlands is termed a wetland complex.

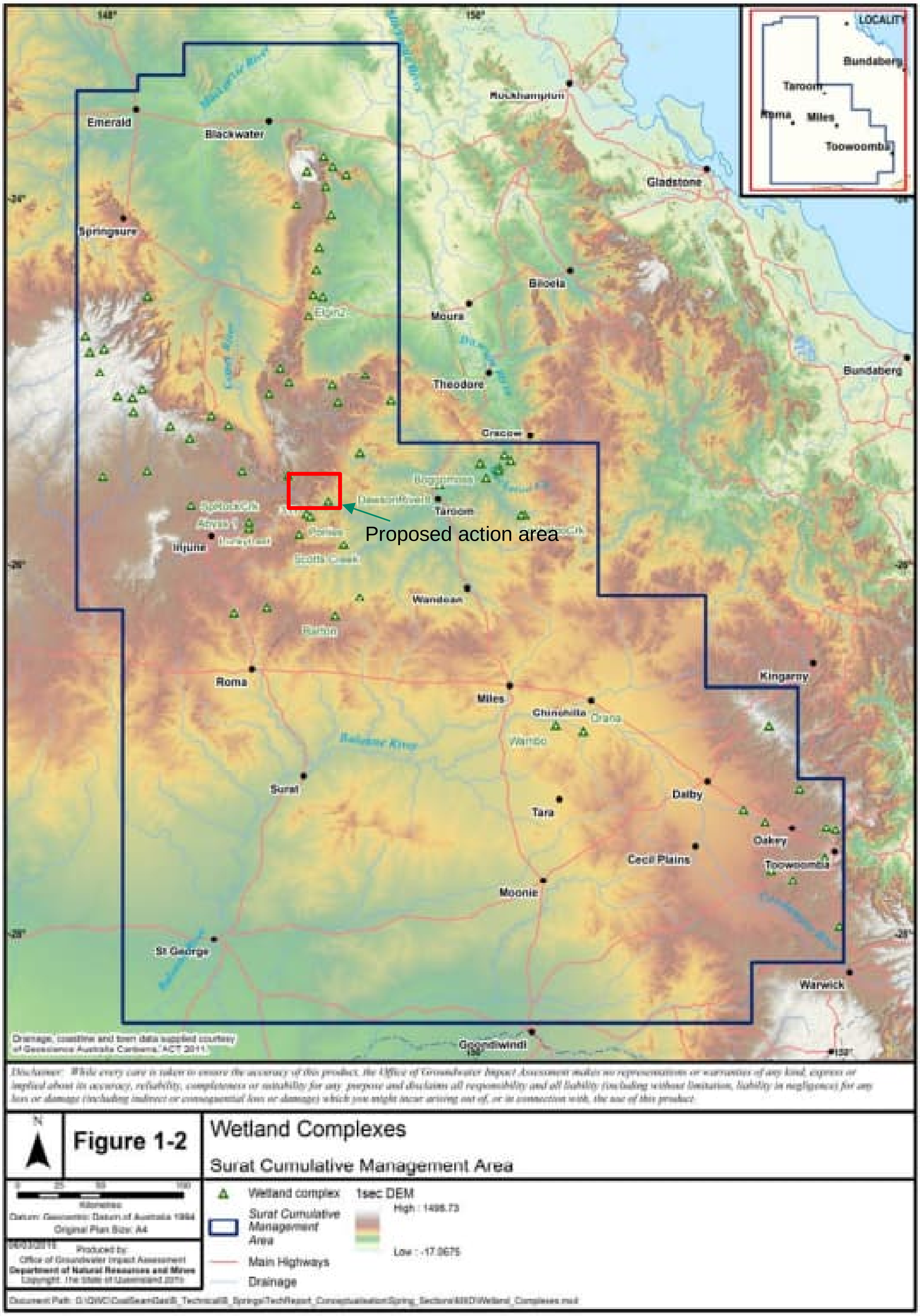


Figure 4-12 **Wetland complexes (OGIA, 2015)**

Spring and groundwater discharge characteristics

As indicated in Section 4.1.1 the Dawson River incises and exposes the Precipice Sandstone resulting in groundwater discharge to the Dawson River and as springs adjacent to the river (Figure 4-13**)**. Erosion of the Evergreen Formation, the confining unit of the Precipice Sandstone, has exposed the aquifer enabling groundwater discharge into the watercourse and springs.

The springs consist of discrete points of groundwater discharge on the riverbanks and in minor tributaries to the Dawson River. They occur within the rocky channel where outcropping Precipice Sandstone bedrock is exposed. Spring discharge (springs) is typically located along bedding planes in the outcropping Precipice Sandstone. The nature of the Dawson River is that regolith is minor. The discharge is limited in extent and permanent (OGIA, 2015).

Yebna 2 spring complex

Whilst most of the springs discharge directly from the Precipice Sandstone where it outcrops, the Yebna 2 spring complex is different. The outcropping geology at the location of the Yebna 2 is Evergreen Formation (OGIA, 2015).

This spring (Plate 1) is identified as discharge of Precipice Sandstone groundwater through thin (< 5 m thick) Evergreen Formation (OGIA, 2015). Figure 4-13 shows the location of the Yebna 2 spring.

Plate 1 Yebna 2 spring within Evergreen Formation sediments

The spring (Plate 1) does not vent enough water to flow continuously (i.e., discharge is less than evaporation – evapotranspiration) such that there is only a discrete area of wet soil and small pool rather than a flowing creek in a drainage feature. The main feature of this spring is that it supports a small wetland ecological community that is disconnected from the main Dawson River.

Based on the data included in Figure 4-11 and Figure 4-13 the Yebna 2 spring is at an elevation of around 250 m AHD and the Precipice Sandstone potentiometric surface is some 255 m AHD. This indicates that the low aquifer hydraulic properties of the Evergreen Formation, even where it is thin, are effective at constraining discharge rates from the Precipice Sandstone.

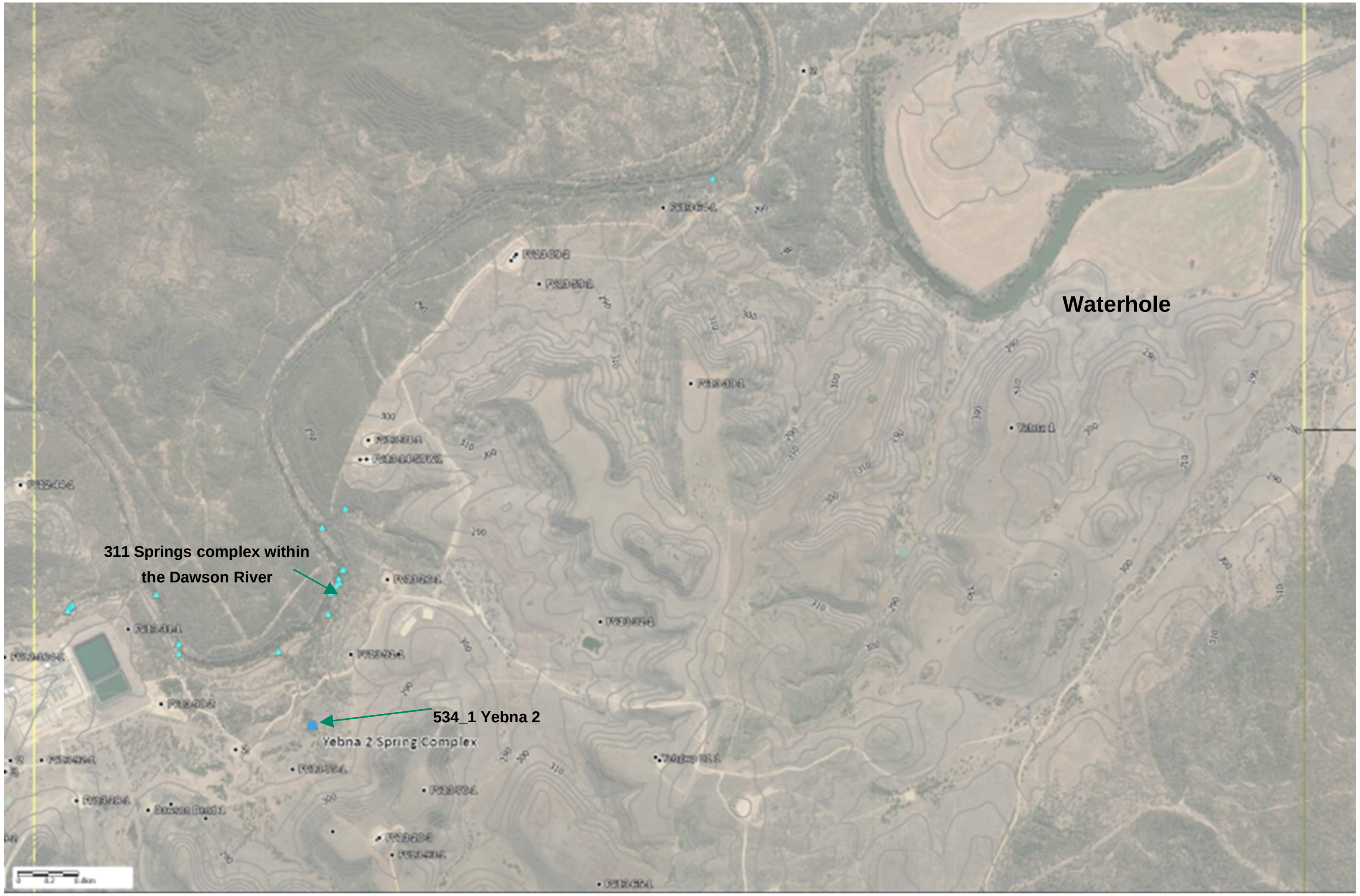


Figure 4-13 **Springs and Yebna-2 in the vicinity of the proposed action area (source: Santos)**

4.2 Groundwater and surface water connectivity

An assessment of site-specific data was conducted to assess the groundwater and surface connectivity within the proposed action area. The following data was assessed:

- Groundwater elevation data
- Hydrochemistry
- Waterhole water balance.

4.2.1 Groundwater elevation data

The available groundwater level monitoring data in the proposed action area included:

- Long-term transient water level monitoring data for three monitoring bores in the Precipice Sandstone
- Long-term transient water level monitoring data for one bore in the Evergreen Formation.

The location of these monitoring bores is shown on Figure 4-14. The groundwater level versus time hydrographs are presented in Figure 4-15.

Hydrographs for the Precipice Sandstone indicate a stable water level trend, with little or no marked response to rainfall variation. Groundwater levels typically range from 274 to 286 m AHD in the proposed action area (as depicted in Figure 4-15).

A slight upward trend is observable in all the Precipice Sandstone monitoring bores, which is likely a response to the reinjection of produced CSG water to this formation after 2015.

Groundwater levels in the Evergreen Formation are lower (deeper depth-to-water measurements) compared to the Precipice Sandstone, ranging from 253 to 256 m AHD (Figure 4-15).

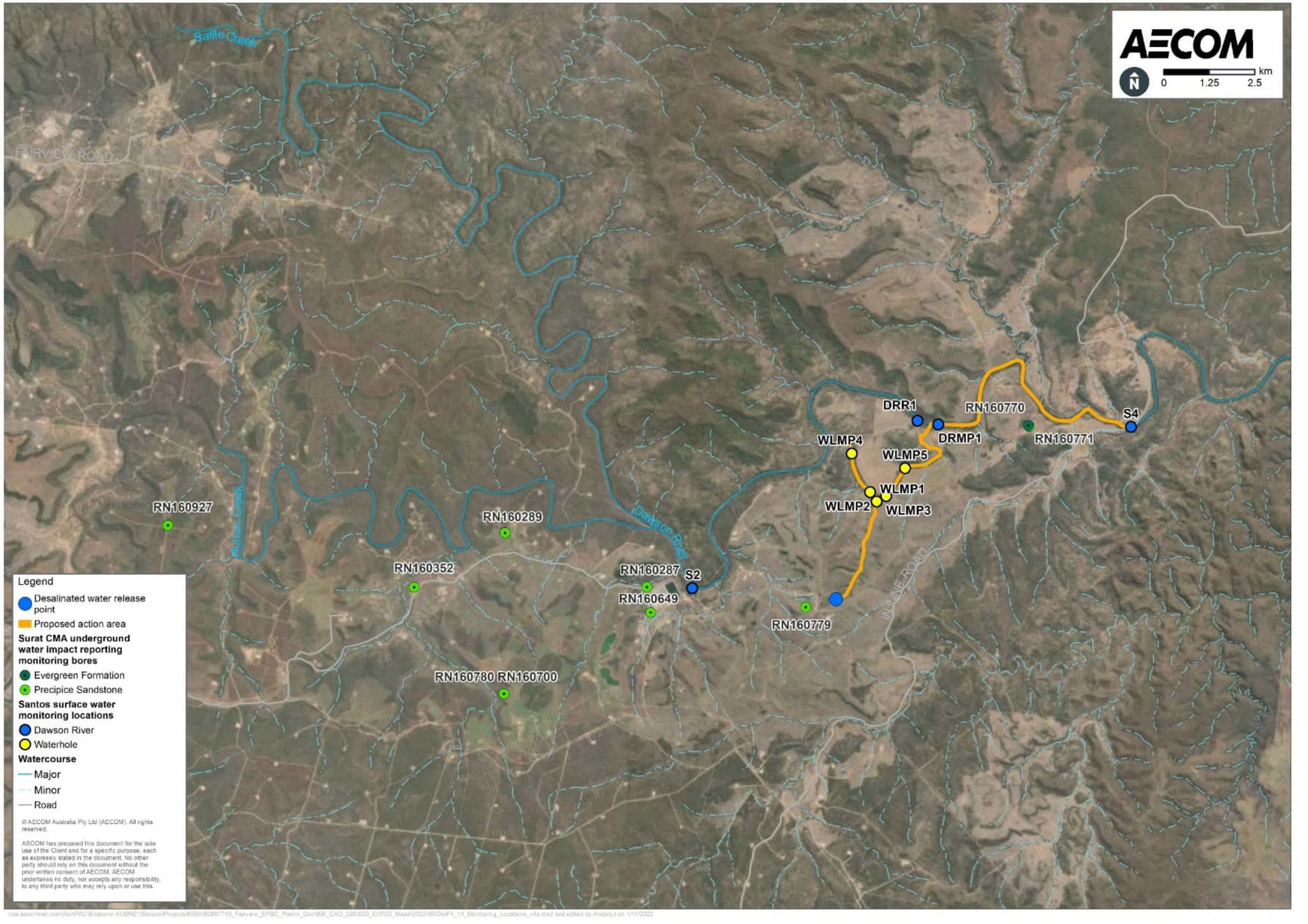


Figure 4-14 Groundwater and surface water monitoring locations

Figure 4-15 Long-term water level trends for bores screened in the Evergreen Formation and Precipice Sandstone (data source - DRDMW Database)

4.2.1.1 Vertical groundwater gradients

Dedicated groundwater monitoring bores RN160771 and RN160770, located immediately east of the waterhole, (Figure 4-14) monitor water levels in the Precipice Sandstone and Evergreen Formation (lower), respectively.

The transient groundwater level data for the Evergreen Formation (Figure 4-15**)** indicates that the bore is unconfined or semi-confined with a depth to water (water table) of approximately 35 m. Short-term groundwater level fluctuation is marked, indicating a seasonal (wet/dry) response of around 2 m. The short-term fluctuations also indicate the Evergreen Formation has limited effective storage. It is noted that the proposed action area is in the northwestern portion of the Surat Basin where the Evergreen Formation is unsaturated (depth-to-water as included in Figure 4.15). Kellett et al (2003) assessment of GAB intake beds recovery (which included the Evergreen Formation) concluded that diffuse recharge rates within the unsaturated zone, are markedly lower than recharge rates from the saturated zone (i.e., the Evergreen Formation in the proposed action area receives limited recharge).

The transient groundwater level data for the Precipice Sandstone (Figure 4-15**)** indicates groundwater conditions at the monitoring bore are sub-artesian with a shallow potentiometric level of around 5 m below ground level (mbgl). Groundwater level fluctuation is limited, indicated by a muted response to climate and CSG water reinjection (slight increase post 2015).

The marked vertical difference in groundwater elevations and water level trends indicates no hydraulic connection (30 m difference in groundwater levels), which also indicates the Evergreen Formation is an aquitard that confines the underlying Precipice Sandstone (i.e., for artesian conditions to prevail in the Precipice Sandstone this aquifer needs to be confined from above (the Evergreen Formation) and below (Moolayember Formation (Table 4.2)) .

It is noted that based on the vertical hydraulic gradient there is an upward and potentially artesian hydraulic gradient from the Precipice Sandstone. As detailed in Section 4.1.2.3 there are no springs recorded corresponding with outcrop of the Lower Evergreen, except for the Yebna 2 spring complex. This discharge of Precipice Sandstone groundwater occurs where the Evergreen Formation is sufficiently thin (< 5 m thick) to facilitate diffuse and discrete discharge, some 8 km west of the waterhole.

The Evergreen Formation, the upper confining unit, dictates artesian flow from the Precipice Sandstone within and adjacent to the proposed action area based on conductance.

4.2.2 Hydrochemistry

Similarity and differences in the chemistry of water from a range of sources can provide evidence of potential connectivity. The following sections present evidence of groundwater-surface water connectivity using water chemistry data from the waterhole, the Dawson River, the Evergreen Formation, and the Precipice Sandstone.

4.2.2.1 Water quality differences

Section 4.1.2 provides baseline groundwater quality data for the Evergreen Formation and the Precipice Sandstone. These data indicate two distinct water types based on the major anion and cation data (Piper plot, Figure 4-16).

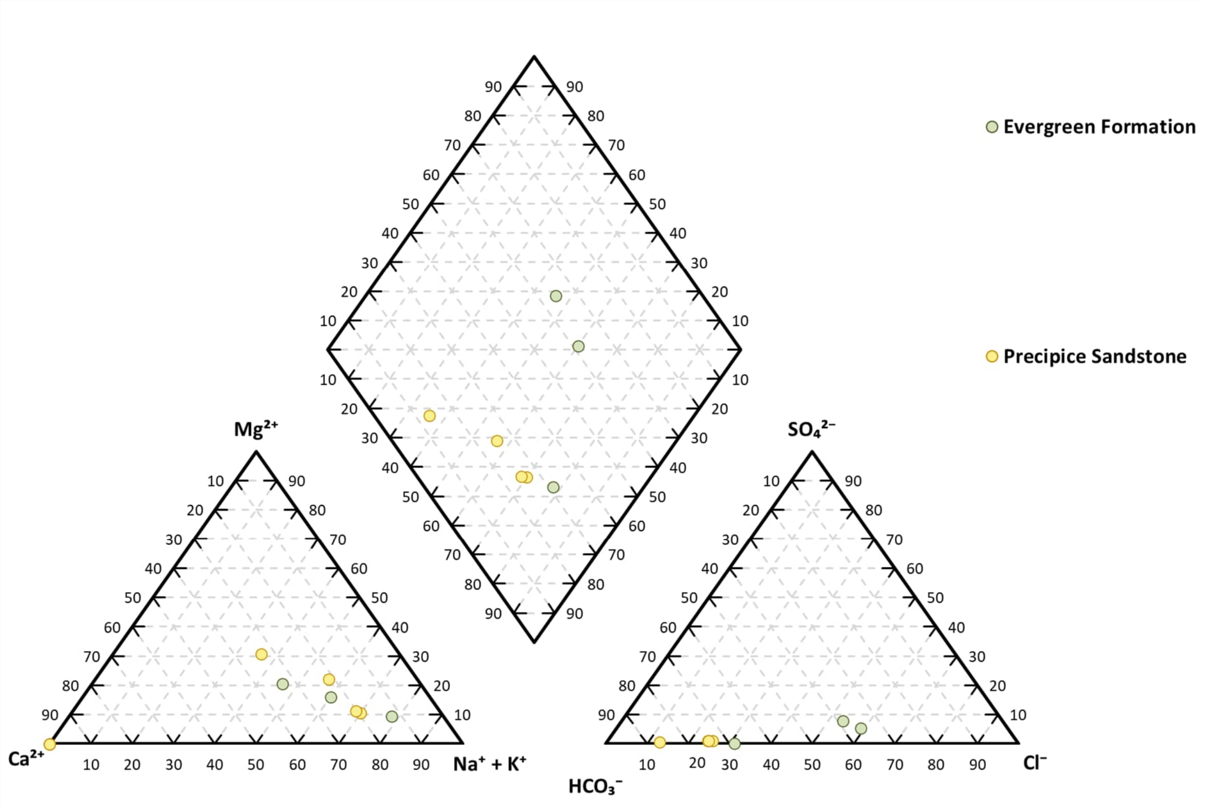


Figure 4-16 Evergreen Formation and Precipice Sandstone Piper plot

No mixed or blended groundwater sample was recognised from the available groundwater quality data, further indicating limited hydraulic interaction between the two hydrostratigraphic units (as assessed in Section 4.2.1.1).

4.2.2.2 Surface water quality comparison

Pre-GLNG surface water chemistry sampling (before desalinated water releases) was conducted by Santos across wet and dry seasons between 2012 and 2014. The surface water sample points, indicated on Figure 4-14, included:

- Five locations within the waterhole (labelled WLMP1 to WLMP5)
- Three locations along the Dawson River (S2, DRR1, and DRMP1).

Surface water chemistry was compared against available groundwater chemistry data from monitoring bores screened across the Precipice Sandstone and Evergreen Formation (refer to Section 4.1.2), located within and adjacent to the proposed action area.

Data has been displayed on a Piper plot (Figure 4-17) and Scholler Diagram (Figure 4-18).

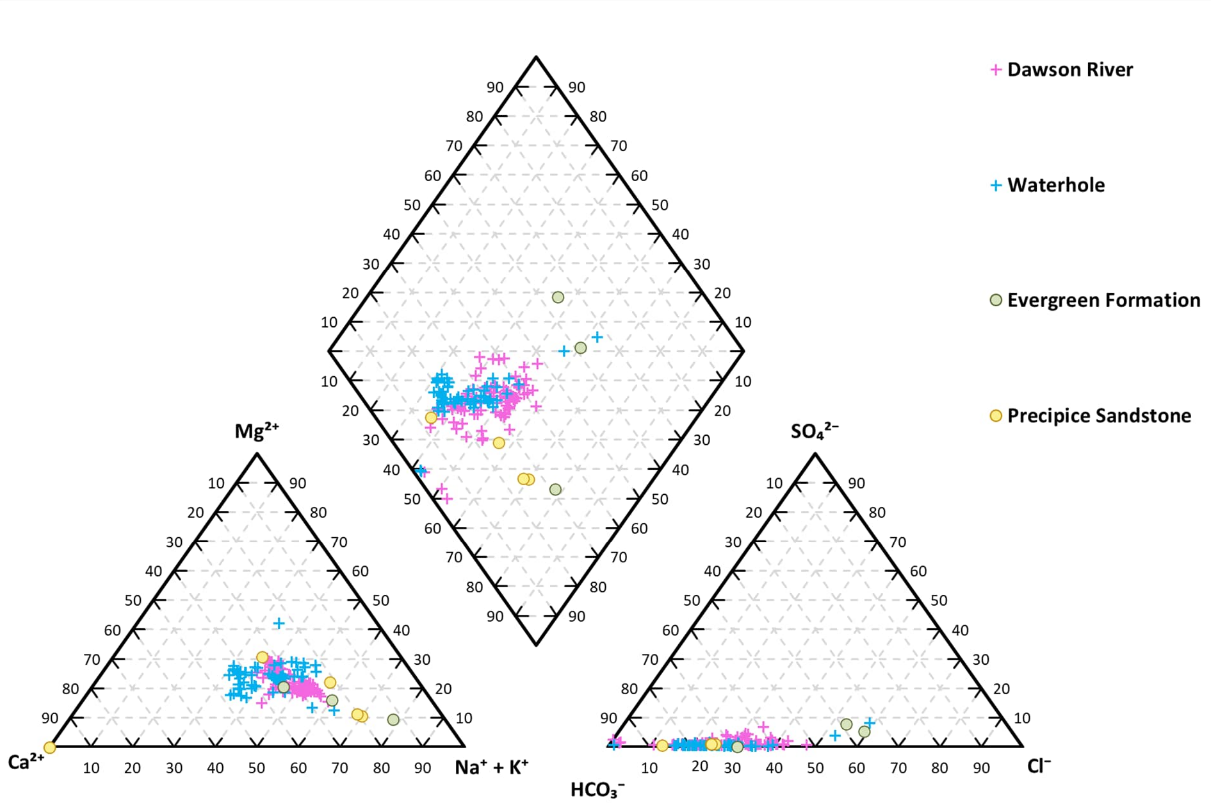


Figure 4-17 Piper plot showing groundwater and surface water hydrochemistry prior to 2015

Table 4-14 summarises the respective water sample data source used to develop the Schoeller diagram in Figure 4-18.

Table 4-14 Inferred water sources for regional water bores and surface water sampling locations

Schoeller Diagram legend	Water source
DRMP1, DRR1, S2	Average values for REMP surface water data
RN160771, RN160779, RN160780	Precipice Sandstone monitoring bores
RN16785 and RN58062	Evergreen Formation registered bores
WLMP1 to WLMP5	Average values of waterhole samples

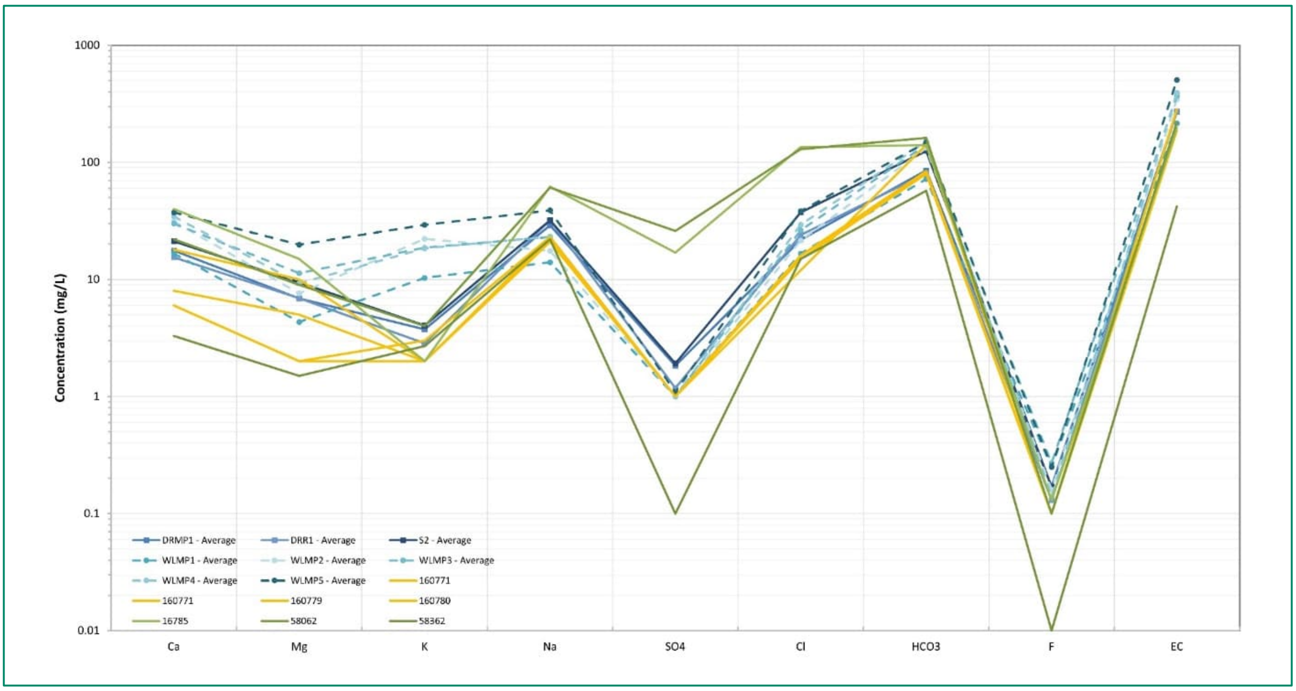


Figure 4-18 **Schoeller diagram showing groundwater and surface water chemistry**

Hydrochemistry monitoring data, taken prior to the GLNG Project desalinated water release into the waterhole, is presented in Figure 4-17. These data indicate the following:

- Groundwater chemistry is variable
- Groundwater chemistry from the Precipice Sandstone shows the greatest similarity with the Dawson River water
- The surface water (average concentrations) for the Dawson River and the waterhole plot within the same location on the Piper plot, which is different to the Precipice Sandstone (due to distance from recharge and aquifer through flow reactions).

Comparison of pre-GLNG desalinated releases surface water quality (average concentrations for S2, DRR1, and DRMP1) and the Precipice Sandstone and Evergreen Formation groundwater quality was included in a Schoeller Diagram (Figure 4.18).

This shows a similarity between the Dawson River surface water and Precipice Sandstone groundwater, as evident from the depleted sulphate concentrations and elevated sodium and bicarbonate concentrations.

The Schoeller diagram of the Dawson River and the waterhole samples (Figure 4-18) indicate elevated potassium in the waterhole compared to the Dawson River and the Precipice Sandstone. The source of the potassium is not considered to be groundwater since both the Evergreen Formation and Precipice Sandstone have lower potassium concentrations (Section 4.1.2).

It is likely that surface waters were mixing within the waterhole, which would be expected given the riverine setting (i.e., large component of runoff entering the waterhole catchment). Evaporative salt concentration build-up and flush, due to the ephemeral nature of the waterhole, which influences the water chemistry.

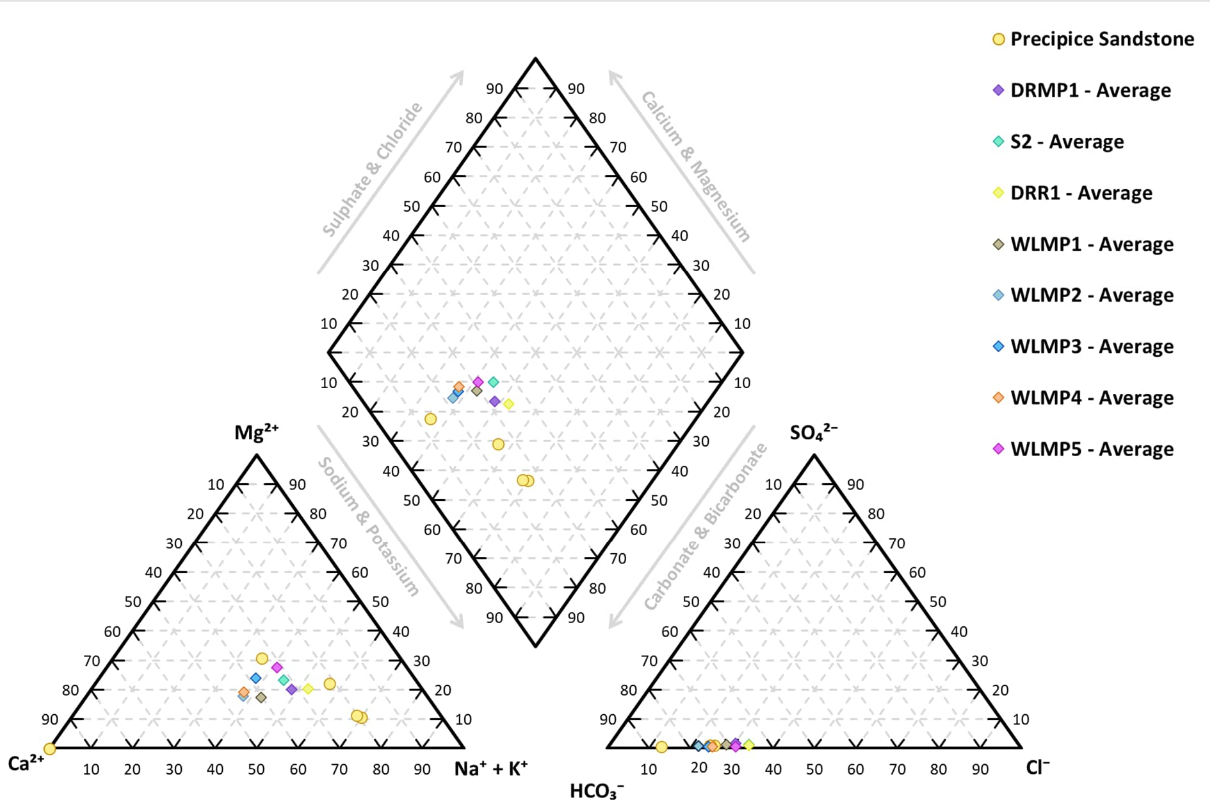


Figure 4-19 Average surface water concentrations and Precipice Sandstone data – Piper Plot

The waterhole hydrochemistry indicates the source water comprises:

- Rainfall runoff (Section 4.2.3)
- Backflow (Section 4.3.1) from the Dawson River when the water level in the Dawson River exceeds an elevation between 249 and 250 m AHD (Section 4.1.1.4 and Section 5.2.2.1).

There is no evidence from the hydrochemical data that there is any connectivity between the waterhole and groundwater in either the Evergreen Formation or Precipice Sandstone.

4.2.3 Waterhole water balance

The waterhole, identified as ephemeral (Alluvium, 2012 and frc environmental, 2019), is almost permanently wet. The permanence of water in the waterhole may be an indicator of groundwater connectivity. However, the permanence of water in the waterhole could also be explained by the periodicity and intensity of rainfall and intermittent flood events.

This section examines that evidence to determine whether the near permanence of water in the waterhole could be explained by rainfall and flood events.

4.2.3.1 Size

The waterhole is described as a large freshwater semi-permanent oxbow lake (floodplain billabong) with an approximate volume of 500 ML (refer to Section 5.2.1.1).

An approximate estimate of the waterhole dimensions and area is shown in Figure 4-20 and comprises:

- Average length 4,000 m
- Average width 80 m
- Area of 320,000 m^2.

The waterhole is estimated to contain 500 ML, (500,000 m^3) (frc environmental, 2019). A survey was undertaken while the waterhole was dry (Alluvium, 2012) and determined:

- The spill crest elevation was 249 m AHD
- The lowest elevation of the waterhole was 245 m AHD
- The maximum storage volume was estimated at 482 ML (some 500 ML).

Based on the estimated waterhole dimensions, the maximum waterhole water depth (acknowledging that the floor of the waterhole is undulating) would be 1.5 m.

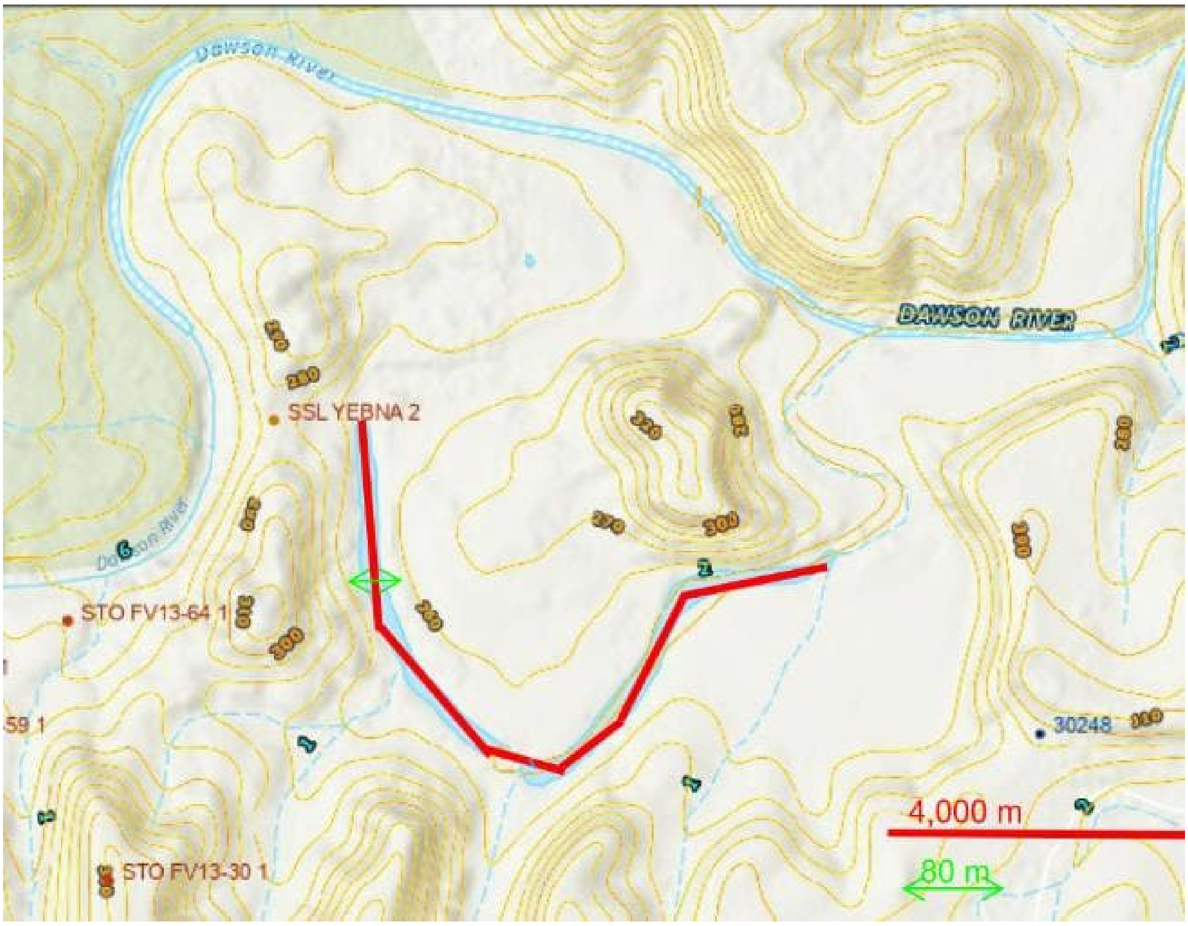


Figure 4-20 Estimated dimensions and elevations of the waterhole (source: GeoResGlobe)

4.2.3.2 Catchment and water budget

Figure 4-3 indicates the total waterhole catchment area to be approximately 14.9 km^2 (to the discharge point at the Dawson River).

Losses due to evaporation from the waterhole, over a maximum available surface area (320,000 m^2), is estimated to occur at a mean evaporation rate of 6.9 mm/day (BoM weather station 043091, 1992 to 2008)[18].

Assuming a conservative water balance approach:

- 10 km^2 of the total catchment drains into the waterhole (10,000,000 m^2)
- Average rainfall of 628.7 mm[19] (Figure 4-21)
- Runoff estimate of a third of rainfall (0.2 m per year)
- Waterhole surface area of 320,000 m^2
- Evaporation data, with a mean evaporation rate of 6.9 mm/day

Table 4-15 Water budget for the waterhole

Attribute	Annual Influx	Annual Outflux*
Rainfall - direct	192,000 m^3	
Rainfall - runoff	2,000,000 m^3	
Evaporation		(0.0069 m/day*320,000 m^2*365 days) 805,920 m^3 (805.9 ML/year)
TOTALS	**2,192,000 m^3**	**805,920 m^3**
* excludes cattle consumption which could be on average 45 L/day per head		

This simple water budget for the waterhole indicates that during an average rainfall year water influx exceeds evaporation and the waterhole storage capacity, resulting in discharge to the Dawson River in the absence of releases of desalinated water.

[18] Closest available evaporation data from Roma Airport
[19] Bureau of Meteorology (BoM) weather station 043015 (Injune Post Office) located approximately 60 km southwest of the proposed action area

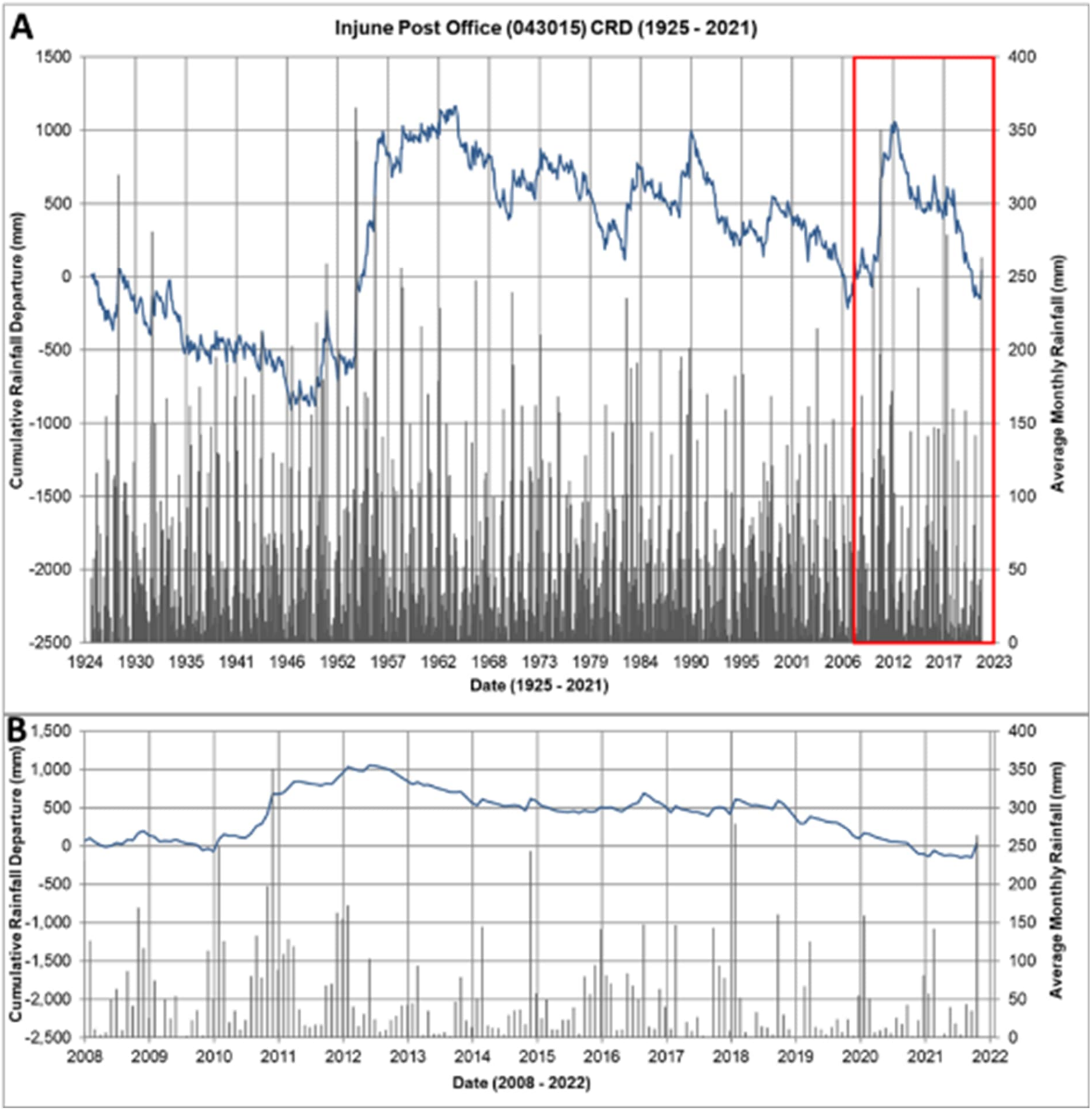


Figure 4-21 **Injune Post Office monthly rainfall data and CRD (BoM 2022). Inset showing 2008 to 2022 data**

4.2.3.3 Decant level and waterhole connection with the Dawson River

The waterhole is a Dawson River meander cut off that has been largely infilled and isolated from the river by alluvial plugs, which created the oxbow lake.

Based on LiDAR survey information (Section 5.2.2.2.2) the outlet watercourse spill point is coincidental with the landholder's access track and is indicated as approximately 249.6 m AHD (± 0.1 m based on the associated LiDAR metadata). This is consistent with information from Santos that indicated the landholders access road across the watercourse is the waterhole spill point. Alluvium (2012) stated the watercourse crest and alluvial plugs allow the storage of some 500 ML in the waterhole.

The waterhole comprises two distinct sub-reaches:

- The upstream sub-reach, which is relatively flat dropping 1 m in 1,400 m (~0.07%) and comprises the waterhole with a storage capacity of approximately 500 ML that is upstream of a fill crest within the outlet watercourse.

- The downstream sub-reach, below the spill point where the topography drops 7 m over the final 250 m (~2.9%) to meet the current Dawson River riverbed.

The waterhole has the potential to connect to Dawson River at both ends during flood conditions, depending on the water/stage height of the Dawson River and accumulation behind the constriction point (Figure 5-6 and Figure 5-7). The upstream connection from the Dawson River to the waterhole is approximately 256 to 257 m AHD. The downstream connection from the Dawson River to the waterhole outlet watercourse spill point is 249.6 m AHD. The stage height of the Dawson River in low flow (or baseflow) condition is approximately 240.5 m AHD (Greenspan, 2012).

This indicates:

- When the waterhole is full, overflow from the waterhole into the Dawson River will occur through the downstream end of the waterhole if the Dawson River stage height is below approximately 249.6±0.1 m AHD at the outlet watercourse spill elevation.
- The Dawson River will flow into the waterhole via the downstream end when the river stage height is greater than 249.6±0.1 m AHD, creating backflow along the outlet watercourse. This requires an increase of approx. 9.0 m in river flow height, compared to baseflow conditions:
  - Based on the S4 gauging record (Figure 5-10) there have been two flood events on record where the flow height was greater than 9 m, one in 2014 and one 2018 and no events greater than the upper waterhole spill elevation of 10.5 m above baseflow stage height.
- The Dawson River will only flow into the waterhole via the upstream end of the waterhole if the flow height of the Dawson River exceeds 256 to 257 m AHD. This requires an increase of 13 m in river stage height compared to baseflow conditions. Records from S4 indicate no flood event between 2012 and 2021 exceeding 9 m in stage height or the 13 m required to enter via the upstream entry (Figure 5-1).
  - However, the restriction in the flood plain noted in Figure 5-6 may constrict floodwaters upstream of the S4 gauging station and not all inundation events may be captured. Reference to flood model data in Figure 5-7 for a 1% AEP event indicates the waterhole and floodplain to be inundated

4.2.3.4 Ephemeral nature

Limited historic information is available regarding the water level fluctuation in the waterhole. A review of available historic aerial photographs was conducted to evaluate the morphology of the waterhole over time. A review of available photographs covering the proposed action area was conducted.

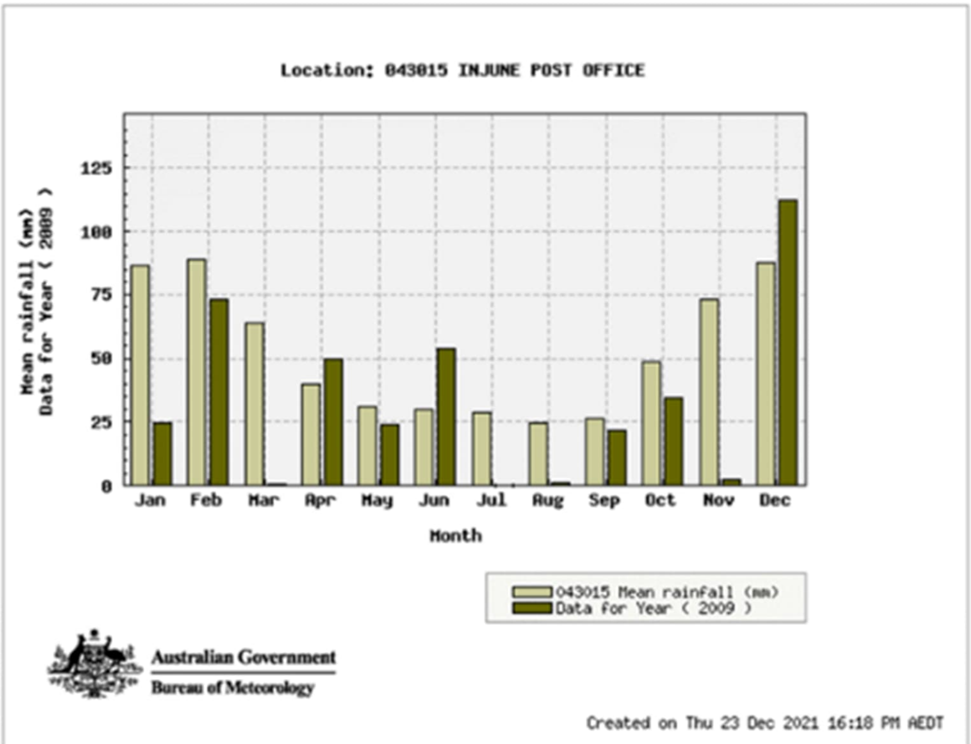
Historic aerial photographs of the waterhole (QImagery[20]) for the following dates have been reviewed:

- 30 July 1963
- 21 October 1964
- 23 May 1977
- 23 May 1986
- 22 August 1994
- 20 July 1997, and
- 20 July 2006.

The available photographs show that there is visible water within the waterhole on all these dates. The volumes of visible water vary depending on the climate conditions prevailing prior to the aerial photograph.

Rainfall data included in Figure 4-21 indicates the lowest rainfall recorded (prior to 2015 when water release to the waterhole began) was in 2009. The total rainfall in 2009 was 399.4 mm, approximately two thirds of the average annual rainfall of 628.7 mm (Figure 4-22).

[20] https://www.business.qld.gov.au/running-business/support-assistance/mapping-data-imagery/imagery/qimagery



Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years
Mean rainfall (mm) for years 1925 to 2021	86.4	88.7	63.6	40.1	31.3	30.0	28.5	24.9	26.7	48.6	73.2	87.9	628.7	97
Statistics	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**	**Years**
Rainfall (mm) for year 2009	24.8	73.4	0.8	49.8	24.0	53.8	0.2	1.4	21.8	34.8	2.2	112.4	399.4	1

Figure 4-22 Mean monthly rainfall and 2009 monthly rainfall measured at Injune Post Office (Station ID: 043015) (BoM 2022)

An aerial photograph from 2010 (Figure 4-24) indicates that no surface water was present within the waterhole at the time of the photograph.

The water (visual or not) within the waterhole validates the ephemeral nature of the waterhole, where prolonged drying cycle(s) and wet phases result in variable inundation.

The absence of water in Figure 4-23 and Figure 4-24 indicates evaporation and agricultural purposes (via excavated pits within the waterhole), exceed rainfall contribution during the period the image was taken. The Dawson River would not have provided backflow to the waterhole in 2009 as it would have remained in a low flow condition.

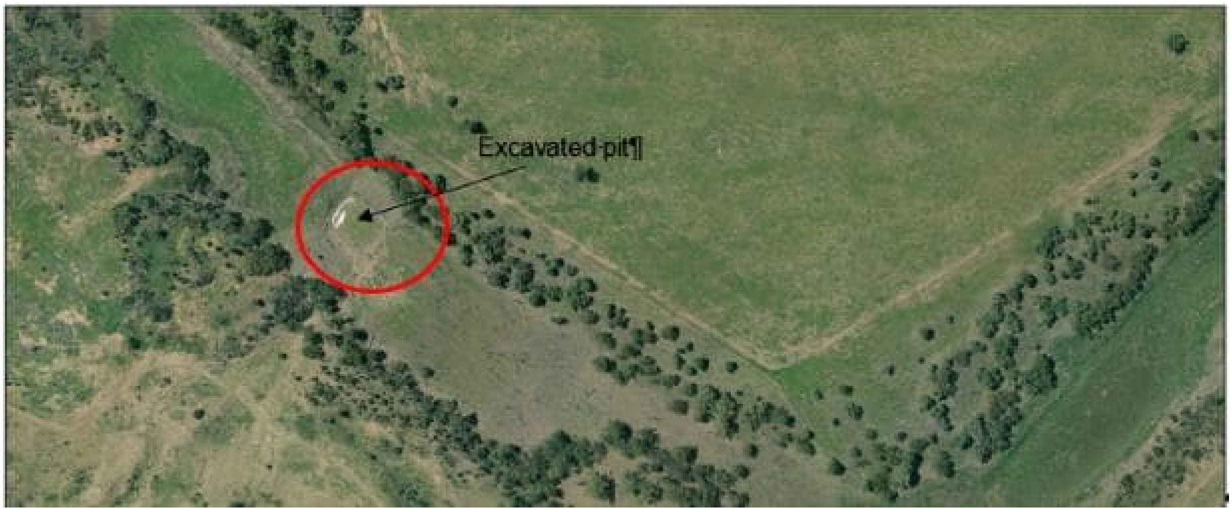


Figure 4-23 Santos supplied aerial image 2010 – close up

Figure 4-23 shows that there is water evident within the excavated pits, which indicates that the excavated pits represent the lowest level of water within the waterhole under dry conditions. The green vegetation evident in the photograph suggests residual water within the soil and vegetation rootzones to maintain growth. This is evidenced by the observed standing water level in the excavation in Figure 4-23.

These observations of ephemeral conditions and in particular the absence of groundwater discharge during drier periods of weather support the conclusion that there is an absence of groundwater connectivity with, and discharge from the Precipice Sandstone, through the Evergreen Formation, into the sediments in the base of the waterhole. Water within the waterhole and associated shallow alluvial groundwater is derived from surface water from within the waterhole catchment and to a lesser degree the Dawson River.

4.2.3.5 Waterhole geomorphology

The waterhole is an oxbow lake, which is relatively stable after undergoing long term accretion and infilling (Alluvium, 2012). The origins of the waterhole are associated with a meander cut-off in the formerly laterally active Dawson River (Figure 4-25).

As described in Section 4.2.3.3, the waterhole comprises two distinct sub-reaches, the relatively flat upstream sub-reach, and the steep downstream sub-reach (7 m drop over 250 m to the Dawson River).

The Dawson River meander in the upstream sub-reach has been largely infilled with colluvium and alluvium to create the waterhole as an oxbow lake (after Alluvium, 2012). The waterhole is located within the central portion of the abandoned meander where limited erosion of the underlying bedrock has occurred (Figure 4-25).

The downstream sub-reach of the infilled meander, which is essentially in the bank of the Dawson River, is subject to episodic infilling (floods in the river deposit significant quantities of sediment in this backflow area) and drainage feature erosion (runoff and discharge from local storms when the river is low) dependent on sequencing of flows in the river and from the waterhole.

Whilst greater streambed erosion/incision of the bedrock would be expected through the neck (Figure 4-25**)** the depth of bedrock erosion is not expected to be as significant away from the neck. This implies there is likely to be less erosion of the Evergreen Formation at the location of the waterhole, therefore maintaining the integrity of the Evergreen Formation as a barrier to potential upward groundwater flow from the Precipice Sandstone.

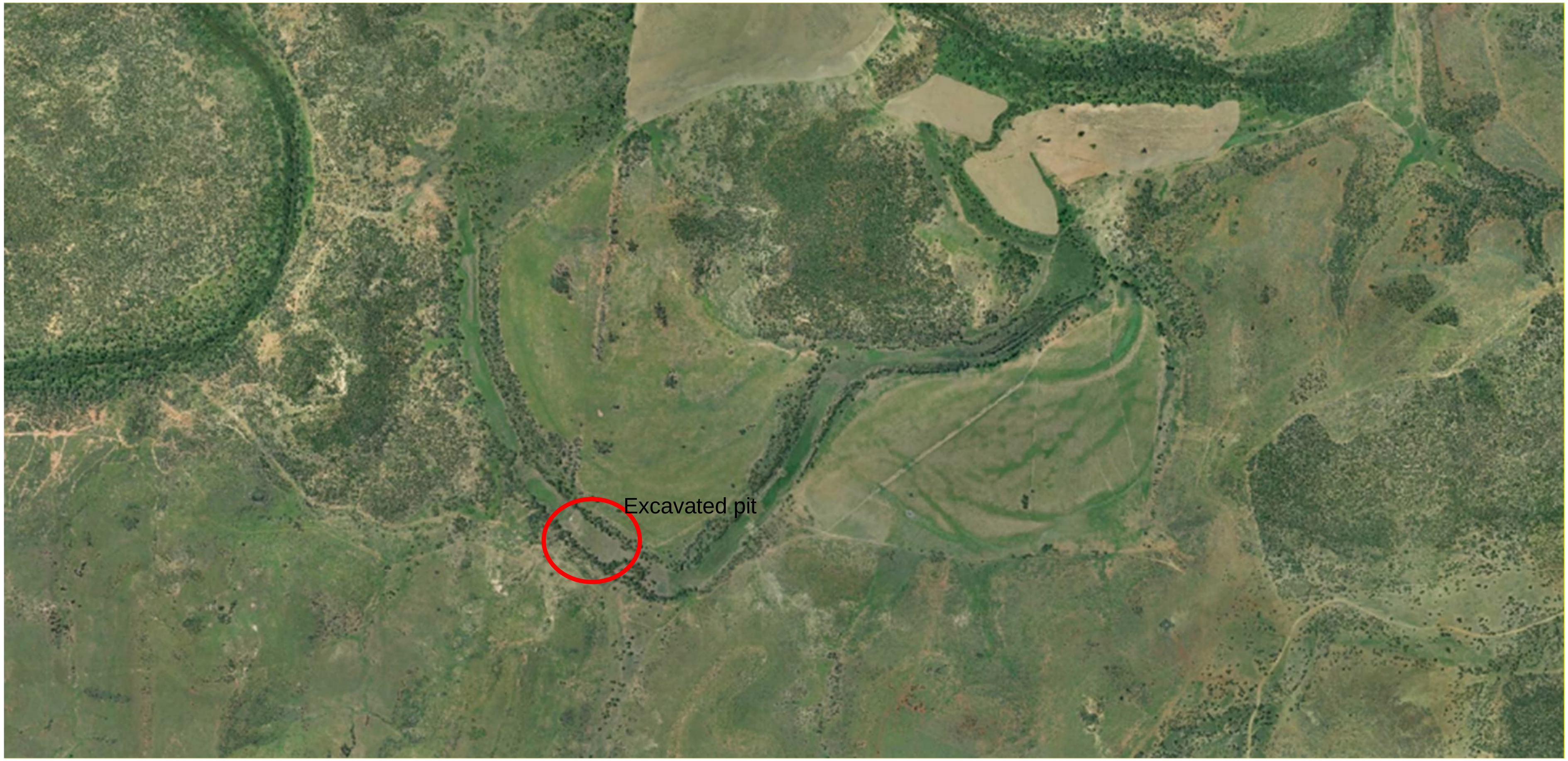


Figure 4-24 Aerial image from 2010 (source: Santos)

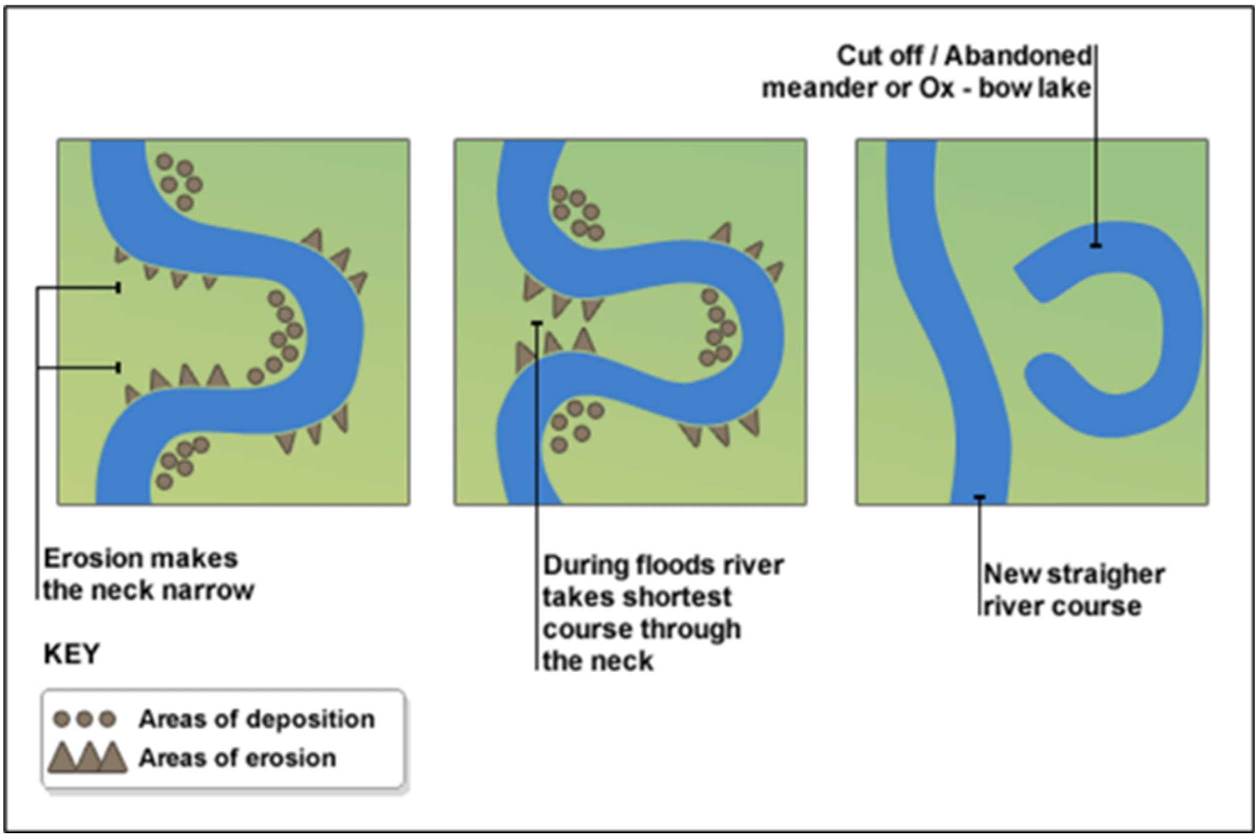


Figure 4-25 Oxbow erosion and deposition actions (source: The Oxbow Lake Syndrome)

4.2.4 Summary of groundwater and surface water connectivity

4.2.4.1 Dawson River groundwater connectivity

Groundwater from the Precipice Sandstone provides considerable baseflow to the Dawson River, based on:

- The hydrochemistry indicating that the main source of surface water within the Dawson River is from the Precipice Sandstone, detailed in Section 4.2.2.2.
- A long history of detailed and site-specific investigations relating groundwater discharge characteristics within the landscape around the Dawson River detailed in Section 4.1.2.3.
- Baseflow measurements within the Dawson River, as presented in Figure 4-10**.**
- Hydraulic gradients within the Precipice Sandstone, as presented in Figure 4-11**.**

Baseflow does not increase, suggesting groundwater ingress does not occur, where the river overlies the Evergreen Formation as indicated in Section 4.1.2.

4.2.4.2 Waterhole groundwater connectivity

Within the waterhole catchment, groundwater from the underlying Evergreen Formation and Precipice Sandstone is not considered to discharge into the waterhole due to:

- The Evergreen Formation is an aquitard, between 40 and 60 m thick, above the Precipice Sandstone at the waterhole (Section 4.2.1 and Figure 4-4), which prevents the discharge of groundwater from the Precipice Sandstone.
- The limited (not evident) hydraulic connectivity between the Precipice Sandstone and Evergreen Formation, based on water quality (Section 4.2.2.1) and ~30 m difference in groundwater elevations (Section 4.2.1.1).

- Hydrochemistry results for the waterhole (elevated potassium, Section 4.2.2.2) indicating:
  - No Evergreen Formation groundwater due to deep groundwater levels (> 35 m) and low potassium groundwater
  - No Precipice Sandstone groundwater due to low potassium groundwater.
- Historical data, showing the waterhole was identified to be dry in the 2010 aerial photograph and during the survey discussed in Alluvium, 2012 (Section 4.2.3.1 [spill crest elevation assessment]).

No discharge from the Evergreen Formation to the waterhole is recognised within the proposed action area because the Evergreen Formation is an aquitard (limited permeability).

4.3 Conceptual model of groundwater surface water connectivity

4.3.1 Waterhole conceptualisation

An illustration of the hydrogeological conceptual model for the waterhole is presented in Figure 4-27**.** The conceptualisation follows the cross-section included on Figure 4-2, along line A – A'.

A conceptualisation of the baseflow contribution of Precipice Sandstone discharge upstream of the waterhole is included in Figure 4.26.

4.4 Impact assessment

The proposed action is the release of up to 18 ML/day of desalinated produced water to the Dawson River via the drainage feature, waterhole and outlet watercourse to the Dawson River. There will be no increase in the existing approved maximum daily release rate (18 ML/day) or total annual volume of 6,570 ML/year. GFD Project water will substitute GLNG Project water, and other water management and beneficial use options such as irrigation will remain in place.

The groundwater assessment considered the potential impacts of the proposed desalinated water release. The assessment considered the geological units underlying the proposed action area, the associated groundwater resources and conditions, and the potential impacts the release could have on the groundwater regimes.

It is noted that the IESC 2018 checklist includes the requirements to consider the potential impacts of the proposed action. A cross reference table indicating the location of required IESC information (Checklist) is provided in Appendix C-1.

It is noted that the desalinated water release pipeline and release point are already constructed and operational for the GLNG Project. Details of these are presented in Section 2.2.1.

4.4.1 Alluvium

Regional scale mapping does not include any alluvium upstream or within the proposed action area (OGIA, 2021). This lack of alluvium on the mapping is related to the fluvial transport and mobility of deposited transient sediments within the Dawson River channel.

At a local scale, saturated colluvium / alluvium sediments, as discussed in Section 4.1.1.4, are not impacted by the proposed release of desalinated water based on the following lines of evidence:

- Within the Dawson River
  - Alluvium is regularly flushed downstream during high flow events (Section 4.1.1). Based on the transient nature of the unconsolidated material, limited thickness, continuity (bedrock outcrop), and fine particle size, the alluvium deposits are not considered a consistent alluvial aquifer.
- Within the waterhole
  - Same or better-quality water entering the waterhole via the desalinated water release
  - The desalinated water release design and construction, plus evidence from use during the GLNG releases, mitigates scour, through existing protection in areas of historical erosion

- When full, the waterhole overtops and discharges to the Dawson River and the Evergreen Formation is an aquitard and as such, the potential loss from the waterhole through downward seepage is limited to within shallow colluvium/alluvium within the infilled meander
- Based on the absence of groundwater inflow from underlying Evergreen Formation or Precipice Sandstone, the waterhole is not considered an Aquatic (Surface Expression) GDE (refer to Section 6.3.1)
- The waterhole is an ephemeral water feature (Alluvium, 2012). The colluvium and alluvium sediments within the waterhole is of limited extent and thickness. These sediments form a shallow aquifer system fed by surface water runoff from the catchment and infiltration from the waterhole
- Chemical (water and sediment), macrobenthic, and ecological water quality monitoring completed under the Receiving Environmental Management Program (REMP) for the existing GLNG desalinated releases have not identified a significant impact on waterhole sediments as discussed in Section 5.3.

4.4.2 Waterhole

Potential impacts of desalinated water releases into the waterhole via the drainage feature and the potential for artificial recharge to groundwater resources was assessed based on the geological information presented in Section 4.1.1 and hydrogeological information provided in Section 4.1.2 and Section 4.2.

The proposed continuation of desalinated water release under the proposed action is not considered to impact on shallow groundwater resources at the waterhole because there is an incomplete potential impact pathway based on the following lines of evidence:

- The minimum 35 m thickness of the Evergreen Formation aquitard (limited groundwater potential, Section 4.4.2) prevents downward migration and losses of surface water to underlying Precipice Sandstone aquifer (Figure 4-27).
- The Evergreen Formation aquitard prevents upward movement and discharge of Precipice Sandstone groundwater (Section 4.2.1.1).

The ongoing release of desalinated water to the waterhole will not penetrate the low permeability aquitard Evergreen Formation; there is negligible risk of surface water entering the high value groundwater resource of the Precipice Sandstone.

The ongoing release of desalinated water to the waterhole shallow colluvium and alluvium will maintain the existing perennial nature of groundwater within the shallow groundwater system of the infilled Dawson River meander.

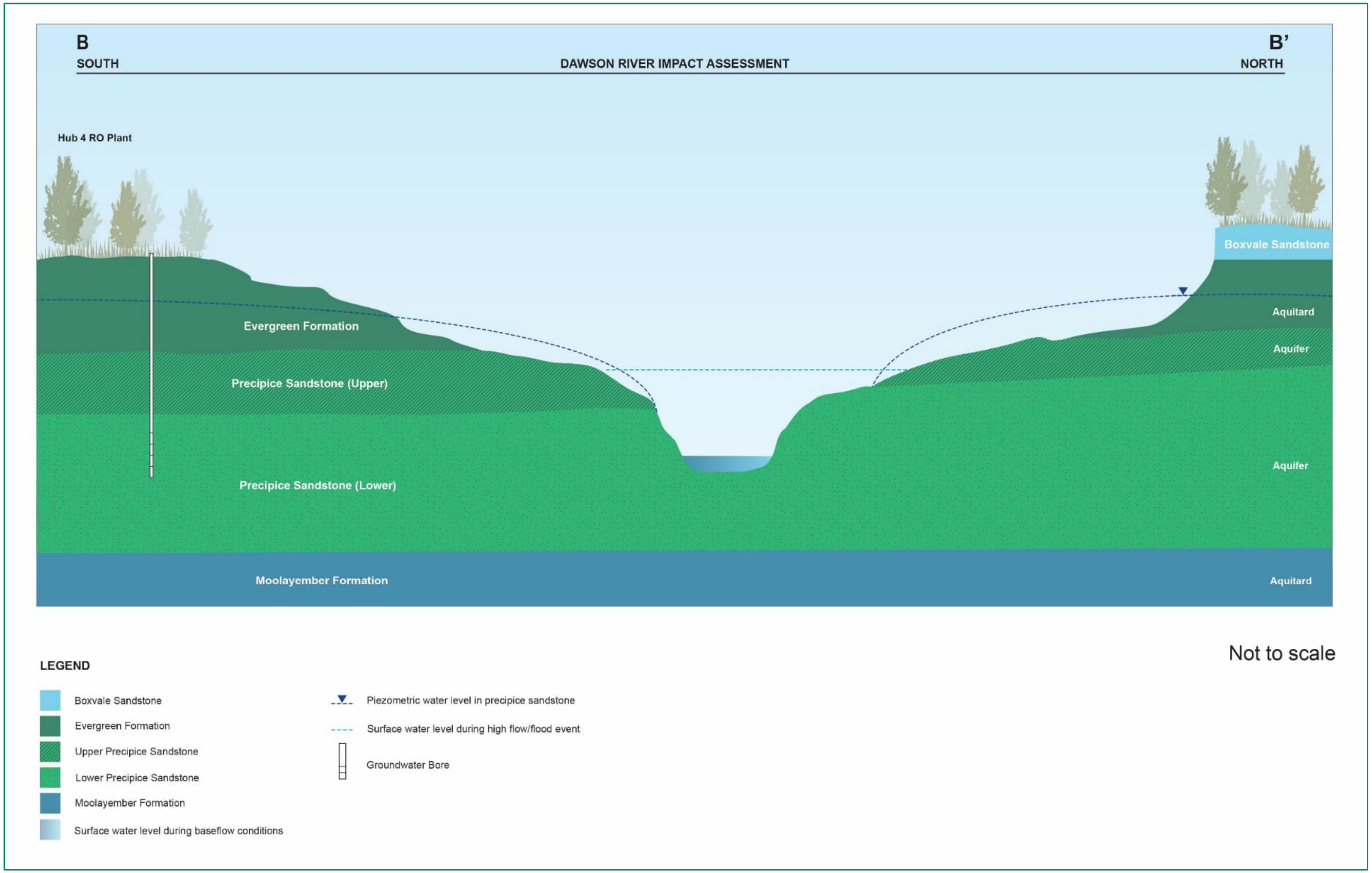


Figure 4-26 Dawson River conceptual groundwater model

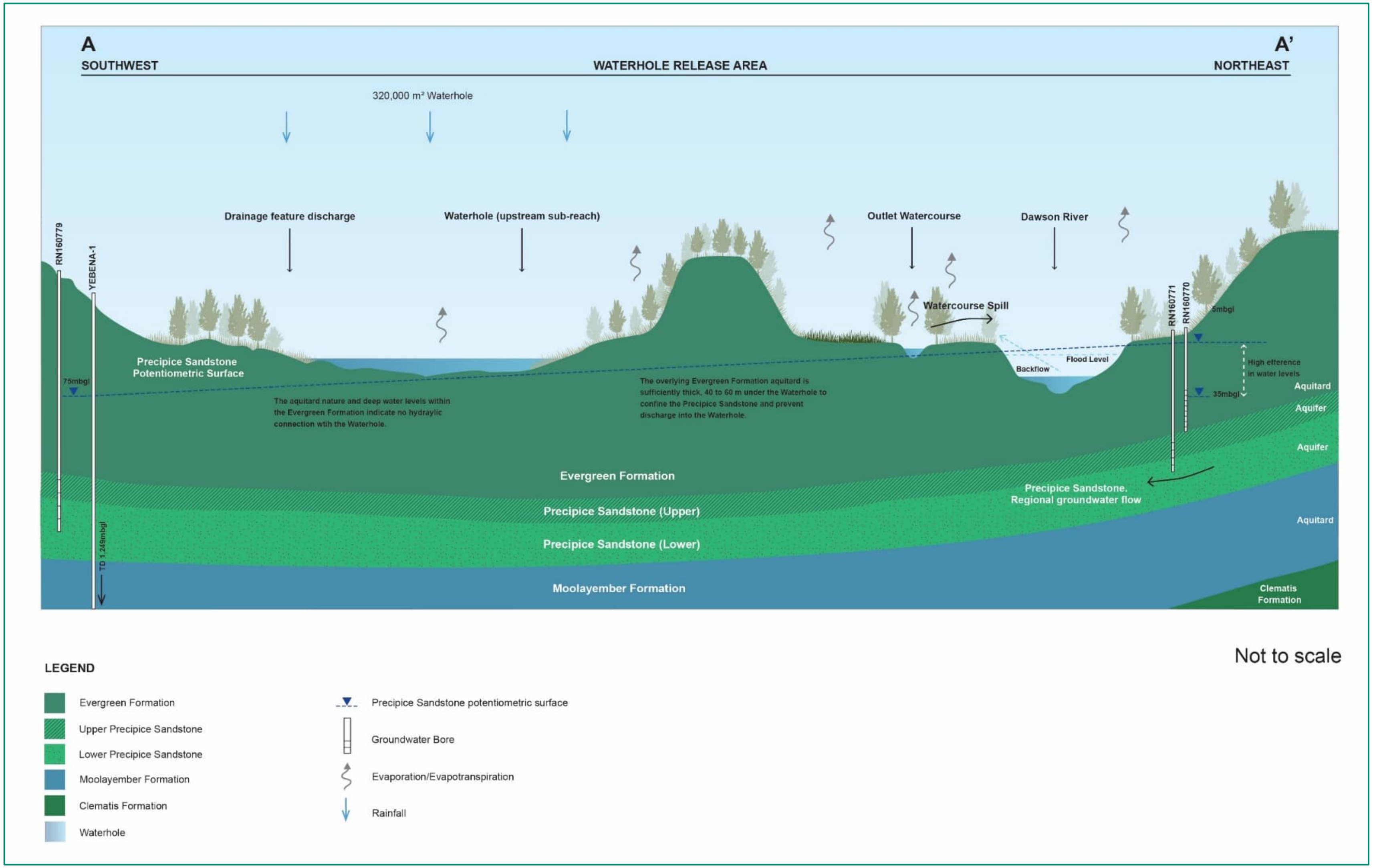


Figure 4-27 Waterhole conceptual groundwater model (refer to Figure 4-2 for cross section location)

4.4.3 Dawson River

As illustrated in the Dawson River conceptualisation (Figure 4-26), the erosion of the Evergreen Formation, incision into and exposure of the Precipice Sandstone, and upward vertical groundwater gradients and springs adjacent to the river facilitates groundwater flow from the Precipice Sandstone into the Dawson River resulting in perennial groundwater discharge upstream of the proposed action area.

Assessment of available data for groundwater and surface water (Section 4.1 and Section 5.3.5) and considering cumulative groundwater impacts (Section 4.4.4) indicates desalinated water releases to the Dawson River will not unacceptably impact groundwater resources as there is negligible risk of surface water entering the Precipice Sandstone (i.e., the groundwater will continue to discharge to surface water).

4.4.3.1 Release impacts

Comments received from the IESC in 2022 related to the proposed discharge of desalinated water into the waterhole (Appendix C-1) included the following considerations:

- Shallow groundwater systems at the project site may be impacted by the releases of desalinated water.
- Desalinated water releases, especially at low flows, are very likely to alter hyporheic water chemistry (assuming hyporheic water is chemically different from the released water) because of advective exchange in the riverbed in places where groundwater inputs are weak or absent, and this will potentially occur for a considerable distance downstream if the releases continue for years to decades.

The conceptualisation, to allow for an assessment of potential impacts (scale, importance, and significance), is the waterhole discharge entering the Dawson River results in a temporary increase in flow rate and rise in the river water. This increased in water level could facilitate advection[21] (if the water quality in the river is different to the hyporheic water) into the riverbank alluvium, which could then be stored, facilitate the accumulation of dissolved substances (associated with desalinated water discharge), and then be released into the river over time.

To assess this possible impact, available information was compiled and assessed, including:

- The assessment of impact within the waterhole has been compiled in this PD, such that this possible impact was considered as it relates to the overtopping of the waterhole and discharge into the Dawson River
  - A hyporheic zone, conceptually for the outlet watercourse between the waterhole and the Dawson River, would have the same water quality as that within the waterhole water. As such no advection is considered to occur.
- No proposed changes to the existing hydrological regimes or water quality than what has happened to date (post-2015)
  - Height of water rise after discharge as per historic results
  - Evaluation of possible advection zone (thickness based on water level change).
- Dawson River alluvium conceptualisation (i.e., non-continuous, transient, and limited effective storage), which indicates limited potential for accumulation of dissolved substances (potentially introduced through desalinated water discharge) and increased risks (no significant impact).
- Water entering the Dawson River via the outlet watercourse is incised before reaching the Dawson River confluence limiting sediment accumulation with no groundwater ingress from the underlying Evergreen Formation aquitard. Therefore the hyporheic water quality would be the same as the waterhole. This is based on:

[21] Advection is the movement of mass entrained in the flow. Solute advection is the movement of dissolved substances because the water they are in is moving.

- Water quality comparison between surface water sample points DRR1 and DRMP1 on the Dawson River (sample location included in Figure 4-14)
- Section 5.3.2 indicates that there is no significant increase in median nutrient concentrations between DRR1 and DRMP1 (as well as S4), indicating that discharges from the waterhole, as represented by WLMP5 data, are not contributing significant nutrient loads to the Dawson River.

Possible impact evaluation

Desalinated water is discharged to the waterhole, fills to an overflow level of 249.6±0.1 mAHD over a number of days (Figure 5-14) before water discharges into the Dawson River. The water is discharged to the waterhole based on the DWB pond release rules specified in Section 2.2 and Section 2.3 that results in between 5 to 15 days per month release with intervening periods of no discharge as indicated in release records provided in Figure 2-3.

Baseflow in the Dawson River (Figure 4-10) is some 250 L/s (22 ML/day) at DRR1 upstream of the confluence with the outlet watercourse, increasing to around 275 L/s (24 ML/day) after the confluence. This increase, some 2 ML/day, is a temporary increase in flow rate (< 10% increase).

The release of desalinated water, via the waterhole, into the Dawson River under baseflow conditions is estimated to result in a temporary increase in the baseline river water level of 0.06 m at the confluence of the waterhole and Dawson River (Table 5-5) and measured as no more than 0.05 m at S4 at a discharge rate of 18 ML/day under baseflow conditions as indicated in Figure 5-14 and Figure 5-15.

Measured data indicates that the waterhole discharge does not result in a significant increase in the natural surface water levels. This indicates little or no potential for advection due to the small water level rise (0.05 m to 0.06 m), similar water quality (above and below the Dawson River – waterhole confluence based on data from DRR1 and DRMP1), and the regular flushing of alluvium (assuming it remained in situ) during higher flow events. The possible impact is, based on available information and the dynamic nature of the Dawson River system, not considered to be accumulative, wide reaching, or significant.

Under extreme dry periods such as those that may occur during extreme droughts (100% AEP) the estimated maximum flow depth increase in the Dawson River at the waterhole confluence and S4 during an 18 ML/day discharge is estimated as 0.14 m (Table 5-7). Under such extreme conditions the discharges would supplement the Scheduled EV of the Dawson River reducing the impact of drought.

4.4.4 Cumulative impact assessment

It is noted that the IESC 2018 checklist (Appendix C) includes the requirements to consider the cumulative impacts. The potential impacts of current and proposed groundwater extraction from known and reasonably anticipated projects in the Surat CMA have been considered for interaction with the proposed action.

The impact assessment, based on the evaluation of proposed water release activities to groundwater resources within the proposed action area, indicate no predicted cumulative impact to groundwater resources within the proposed action area or adjacent areas.

The potential impacts of current and proposed groundwater extraction in the Surat CMA are considered not to increase risk to the groundwater resources as a result of interaction with this proposed action.

4.4.4.1 Summary of existing and proposed developments

To assess cumulative impacts, the Surat UWIR (OGIA, 2021) considered the following:

- CSG is the dominant, and expanding, resource development activity in the Surat Basin from five major operators – QGC, Santos, Origin Energy, Arrow Energy and Senex.
- The existing and proposed production footprint has increased by about 8 % compared to the previous UWIR (2019 to 2021).
- As at the end of 2020, there are approximately 8,600 CSG wells in the Surat CMA. This is likely to increase to 22,000 based on the current plans of approved development.

- There has been a significant increase in associated cumulative water extraction by CSG since 2014, to the current level of around 54,000 ML/year from about 8,600 wells.
- The majority (41,000 ML/year) of associated water extraction has been in the Surat Basin, while in the Bowen Basin it has remained relatively stable in recent years at about 9,000 ML per year.
- Total associated water extraction by coal mines in the Surat Basin in 2020 has been less than 1,000 ML/year, which is less than 2% of the overall associated water extraction in the Surat Basin.
- OGIA has compiled information about the CSG and coal mining development footprint and timing for existing as well as proposed development. This information is used as input to the regional groundwater flow model to predict impacts and analysis of groundwater trends.

4.4.4.2 Predicted cumulative impacts

Surat CMA predictive modelling

The 2021 UWIR provides predicted cumulative long-term impacts on groundwater levels for the Precipice Sandstone, at springs adjacent to the proposed action area; 311 spring complex and Yebna 2 (Figure 4-13).

The predicted drawdown within the Precipice Sandstone at these two springs are included in Table 4-16.

Table 4-16 Summary of predictions of impact on springs within the proposed action area (source: OGIA, 2021)

Spring group	Spring complex	Source aquifer	Maximum drawdown (m)	Timing to maximum impact (years)
311 / Yebna 2	311	Precipice Sandstone	0.2 – 0.7	38 - 39
	Yebna 2		0.2 – 0.6	25 - 39

These limited long-term drawdown predictions are not sufficient to alter vertical groundwater within the proposed action area. Therefore, the cumulative impacts do not increase the potential risks to the groundwater resources.

4.4.5 Significant impact assessment

Based on the findings of the groundwater assessment plus the implementation of existing mitigation and controls, it is **unlikely** that the proposed action will result in a significant impact (as defined in Significant Impact Guideline 1.3) to water resources relating to groundwater.

As per Significant Impact Guideline 1.3 (DAWE 2013), an action is likely to have a significant impact on a water resource:

> "…*if there is a real or not remote chance or possibility that it will directly or indirectly result in a change to:*
>
> - *the hydrology of a water resource*
> - *the water quality of a water resource*
>
> *that is of sufficient scale or intensity as to reduce the current or future utility of the water resource for third party users, including environmental and other public benefit outcomes, or to create a material risk of such reduction in utility occurring.*"

Assessment of potential significant impacts of the proposed action for groundwater resources is based on the information provided in this Section. A summary of the assessment of the impacts of the event-based release against criteria contained in Significant Impact Guideline 1.3 (DOTE 2013b) is presented in Table 4-17.

Table 4-17 Assessment against significant impact criteria for groundwater resources

Category	Assessment Criteria	Significant impact	Justification
Changes to hydrogeological characteristics	a) Changes in the water quantity, including the timing of variations in water quantity	Unlikely	The proposed action is a continuation of desalinated water releases for the GFD Project are anticipated to be up to 18 ML/day as required under the water management regime currently in place. There is no connectivity between underlying Precipice Sandstone as the primary aquifer for water resources and the waterhole, outlet watercourse, or Dawson River within the proposed action area. The desalinated water releases result in an observed temporary increase of up to 0.5 m within the waterhole and between 0.05 m to 0.06 m in the Dawson River level under baseflow conditions during release events. The waterhole alluvium/colluvium is considered to be in equilibrium with the waterhole since the shallow groundwater system in the waterhole is surface water fed. Desalinated water release does not significantly impact the shallow groundwater resource in scale or intensity including recharge rates over pre-existing conditions under the GLNG Project. The transient alluvium in the Dawson River is also in equilibrium with Dawson River water and has limited effective storage. Desalinated water releases increase water depth between 0.05 and 0.06 m during release events and slowly increase to these levels over several days. As such there is limited impact on water resources contained in transient sediments of the Dawson River under baseflow and flood flow conditions.
	b) Changes in the integrity of hydrological or hydrogeological connections, including substantial structural damage (e.g. large-scale subsidence)	Unlikely	The proposed action is not anticipated to modify the surface water hydrological connectivity associated with the Dawson River, or waterhole from current conditions occurring under the GLNG Project. Increased water levels within the Dawson River associated with desalinated water releases will not increase sufficiently (measured as no more than 0.05 m at S4) to reverse groundwater flow gradients, such that the Dawson River is always a gaining river at the release point. In the absence of connectivity there is no risk of surface water entering the Precipice Sandstone.

Category	Assessment Criteria	Significant impact	Justification
	c) Changes in the area or extent of a water resource	Unlikely	The project action is anticipated to maintain the existing waterhole water volumes and extent range. Changes to the area or extent or water resources within Dawson River are expected to be minor in baseflow conditions, and negligible in flood conditions.
Changes to water quality	a) The ability to achieve relevant local or regional WQOs is materially compromised, and as a result the action:	Unlikely	
	i. creates risks to human or animal health or to the condition of the natural environment as a result of the change in water quality	Unlikely	The precipice Sandstone forms the primary viable groundwater resource for abstraction within the proposed action area. The Precipice Sandstone does not have connectivity with surface waters within the proposed action area. Shallow colluvium/alluvium is limited to the waterhole and is fed by and in equilibrium with surface waters. Water quality data for surface waters indicates that there is no significant increase in physicochemical or parameters compared to desalinated water prior to release bar ammonia and zinc which both naturally exceed the respective WQO in the receiving environment based on pre-GLNG Project data for the waterhole and upstream water quality in the Dawson River. Desalinated water releases are not contributing significant loads or alteration of water quality within the waterhole or that may impact shallow groundwater resources that are in equilibrium with surface waters.
	ii. substantially reduces the amount of water available for human consumptive uses or for other uses, including environmental uses, which are dependent on water of the appropriate quality	Unlikely	The proposed action is the release of desalinated water and does not reduce groundwater resources within viable aquifers in the proposed action area.

Category	Assessment Criteria	Significant impact	Justification
	iii. causes persistent organic chemicals, heavy metals, salt or other potentially harmful substances to accumulate in the environment	Unlikely	There is no connectivity between underlying Precipice Sandstone as the primary aquifer for water resources and the waterhole, outlet watercourse, or Dawson River within the proposed action area and as such no impact to the associated water quality of the aquifer. Existing water and sediment quality data does not indicate accumulation of chemicals in downstream waters or sediments that may be associated with desalinated water releases. Specific persistent organic chemicals are discussed in **Section 8.3** and have not been identified to pose an unacceptable risk.
	iv. seriously affects the habitat or lifecycle of a native species dependent on a water resource, or	Unlikely	Impact to habitat and life-cycles of native species dependent on groundwater are assessed in: Section 6.4 discusses potential impacts to GDE. Section 7.0 discusses potential impacts to MNES turtles
	v. causes the establishment of an invasive species (or the spread of an existing invasive species) that is harmful to the ecosystem function of the water resource.	Unlikely	Impact to habitat and life-cycles of native species dependent on groundwater are assessed in: Section 6.4 discusses potential impacts to GDE including stygofauna Section 7.0 discusses potential impacts to MNES turtles
	b) There is a significant worsening of local water quality (where current local water quality is superior to local or regional WQOs)	Unlikely	The waterhole is not hydraulically connected to the Precipice Sandstone or Evergreen Formation. The shallow alluvium / colluvium groundwater of the waterhole is surface water fed and in equilibrium with surface water. The proposed action is an ongoing release of desalinated water in line with pre-existing releases under the GLNG Project and is not considered to have a significant impact on pre-existing groundwater quality.
	c) High quality water is released into an ecosystem which is adapted to a lower quality of water	Unlikely	The waterhole is not hydraulically connected to the Precipice Sandstone and will not have a significant impact to the groundwater resource. The shallow alluvium / colluvium groundwater of the waterhole is surface water fed and in equilibrium with surface water. The proposed action is an ongoing release of desalinated water in line with pre-existing releases under the GLNG Project and is not considered to have a significant impact on pre-existing groundwater quality.

Category	Assessment Criteria	Significant impact	Justification
Significant Impact Conclusion The proposed action is considered **unlikely** to have a significant impact on groundwater resources as: • The action will not directly or indirectly result in a significant change to the hydrogeological characteristics of a water resource or the water quality of a groundwater resource that is of sufficient scale or intensity as to reduce the current or future utility of the water resource for third party users, including environmental and other public benefit outcomes, or to create a material risk of such reduction in utility occurring.			

5.0 Surface water resources

Chapter summary

Review of potential impacts of the proposed action on surface water resources primarily references empirical data from baseline studies, the REMP and Santos gauging data for water levels and discharges collected between 2013 and 2022. Some reference has been made to historical modelling where no empirical data is available.

Hydrology

Desalinated water releases have been monitored in the receiving environment since 2015 for flow at WLMP1 in the waterhole and S4 at Yebna crossing and for water quality, sediment quality and biological indicators at three locations in the waterhole and three locations in the Dawson River.

The waterhole has become more of a perennial feature since commencement of desalinated water releases in 2015 with a water depth of 1 m. Gauging data for water depth at WLMP1 in the waterhole indicate water depth ranges between +0.4 m to -0.5 m at its maximum and generally results in less than 0.5 m variability between release events. This allows the waterhole to act as buffer storage that in turn delays desalinated water discharge to the Dawson River by two to three days as the waterhole fills and eventually spills to the Dawson River.

Measured increases in water depth in the Dawson River at Yebna Crossing (S4) under both 18 ML/day and 13.5 ML/day desalinated water discharges are no more than 0.05 m. The measured 0.05 m water level increase occurs slowly over several days depending on the duration of the desalinated water release event. The measured and calculated water depth increase during flooding conditions within the Dawson River due to the proposed action is negligible and imperceptible.

In contrast, water level increases in the waterhole and Dawson River in response to rainfall are rapid even for relatively small rain events within the waterhole and upper Dawson River catchment. As such, the proposed action is a continuation of the same release regime and does not significantly alter the pre-existing current hydrological conditions in the waterhole or the Dawson River.

Water quality

Review of both water quality data from baseline assessments and post-desalinated water releases in the waterhole have not identified significant impacts to water quality or associated ecological and biological quality.

Monitoring data from current desalinated water releases indicates the receiving water achieves State EA contaminant limits (CL) for all parameters at the S4 compliance point in the Dawson River.

Review of water quality monitoring data indicates an overall improvement in water quality in the waterhole and no significant change to water quality in the Dawson River compared to upstream reference data. Identified parameters exceeding a WQO have been found to be associated with pre-existing upstream conditions and not associated with desalinated water releases.

Review of sediment quality data for the GLNG Project REMP monitoring did not identify significant impacts on waterhole and Dawson River sediment quality. No parameters were detected above sediment Default Guideline Value (DGV) in the waterhole or Dawson River. Aluminium, iron and manganese (common earth elements) exceeded the REMP Local Trigger (LT) upstream of the waterhole confluence with local trigger (he Dawson River but decrease downstream indicating that releases are not adding to sediment metal loads in the Dawson River.

Ecological and biological data indicates a high degree of variability within the waterhole and Dawson River. Overall, long term trends in macrobenthic indicators do not display a significantly increasing or decreasing trend outside year-on-year variability during current desalinated water releases. Fish survey data indicates a net increase in fish diversity in the waterhole and no significant change from existing conditions in the Dawson River compared to upstream reference locations. Non-native fish were observed in the waterhole in 2015 and in 2017 but have not been recorded in the waterhole since 2017. No non-native fish species have been identified in Dawson River survey data. Observed non-native fish in the waterhole are recognised as being common in the Upper Dawson catchment by the Queensland Government.

Overall, desalinated water releases have not impacted the aquatic environmental values and has enhanced the overall waterhole habitat for aquatic species. The proposed action is not anticipated to significantly change the current hydrological ecological and biological system of the waterhole or Dawson River as a continuation of existing desalinated water releases. Based on assessment of the proposed action against significant impact guidelines applicable for water resources, no significant impact has been identified.

As discussed in Section 2.3, Santos is seeking Commonwealth approval to release up to 18 ML/day of desalinated produced water to the Dawson River via the drainage feature, waterhole and outlet watercourse to the Dawson River using the existing infrastructure at HCS04 ROP. There will be no increase in maximum daily release rate (18 ML/day) or total annual volume as GFD Project water will replace GLNG water, and other water management and beneficial use options such as irrigation are in place. For the purposes of this surface water resource assessment the waterhole and watercourse connecting it to the Dawson River are considered as one entity.

This section provides requested information regarding desalinated water releases within the original RFI (Appendix A) following removal of event-based releases from the proposed action, together with IESC requirements (revised cross-reference table within Appendix C-1), and DCCEEW and IESC comments received on the initial PD (response tables within Appendix B2 and Appendix C-2 respectively).

DAWE (2021 – now DCCEEW) requested further information regarding potential impacts of the proposed action to hydrological characteristics and water quality of the Dawson River and waterhole system (consisting of the drainage feature, waterhole, and watercourse). DAWE requested information includes (and with information located in):

- baseline flow regime of the Dawson River with consideration of existing water releases (Section 5.2.2)
- predicted volume, timing frequency and duration of proposed releases (Section 2.3.1)
- potential future flow regime of the Dawson River (Section 5.5.5)
- existing and future water quality in the Dawson River, waterhole and drainage feature including evapotranspiration may influence water quality (Section 5.3 and Section 5.5.5)
- modelling of water quality and hydrological regimes, developed at an appropriate spatial and temporal scale, to provide an understanding of potential impacts to flow regimes, surface and groundwater connectivity (Section 5.1 where no empirical data is available), and
- predicted release curves including assumptions for the respective models (Section 2.3.1).

Applicable items of the IESC checklist addressed in the assessment includes details relating to:

- hydrological regime of all watercourses, standing waters and springs across the site (Section 5.2)
- surface water modelling including assumptions and limitations (Section 5.1)
- surface water impact assessment including cumulative impact assessment (Section 5.5)
- proposed mitigation and management options to reduce risks to an acceptable level based on the environmental objectives including assessment of adequacy of proposed measures (Section 5.6), and
- proposed surface water monitoring programs to enable detection and monitoring of potential impacts (Section 9.2).

Appendix C-1 provides cross references for applicable IESC checklist requirements relating to surface water resources.

Comments received from the IESC in 2022 also requested information regarding:

- potential increases regarding increases in water depths and duration of water depth under an 18 ML/day release regime (Section 5.2.2)

- potential increases in non-native pest species in the waterhole (Section 5.3.4)
- chemical composition of desalinated water including variability and how ionic matching with receiving water is completed (Section 5.3.1 and Section 0)
- variability in background water quality during periods of no release (Section 5.3.5)
- potential increases in loads of water quality chemicals that exceed existing contaminant limits and water quality objectives (Section 5.3.5.1 and Section 2.2.1.3)
- effects of rapid and frequent rises in water levels on habitat (Section 5.2.2.3.3 and Section 5.5.1), and
- assessment of sediment quality and potential accumulation and migration of chemicals in sediments (Section 5.4).

For the purposes of this section including the assessment of potential impacts of the proposed action to the hydrological characteristics and water quality of the Dawson River, drainage feature and waterhole, the following assumptions have been made:

- Baseline conditions referenced for this PD consist of:
  - water quality data collected between 2011 and 2015, before the start of desalinated water releases in 2015, and
  - water quality data collected from the Dawson River upstream of the waterhole – Dawson River confluence (DRR1).
- As there will be no change to the existing desalinated water release regime, it is considered that there will be no change (increase) regarding the flow regime, hydrology and water quality of the drainage feature, waterhole, and Dawson River.
- The Dawson River within the proposed action area extends from the confluence of the waterhole with the Dawson River to monitoring location S4 at Yebna Crossing as indicated in Figure 5-1. This assessment has included potential impact further downstream where required.

Where applicable, the impact assessment utilises existing empirical monitoring data to evaluate the potential impacts of the proposed action to surface water resources, and where applicable, such as in the absence of empirical data, model predictions.

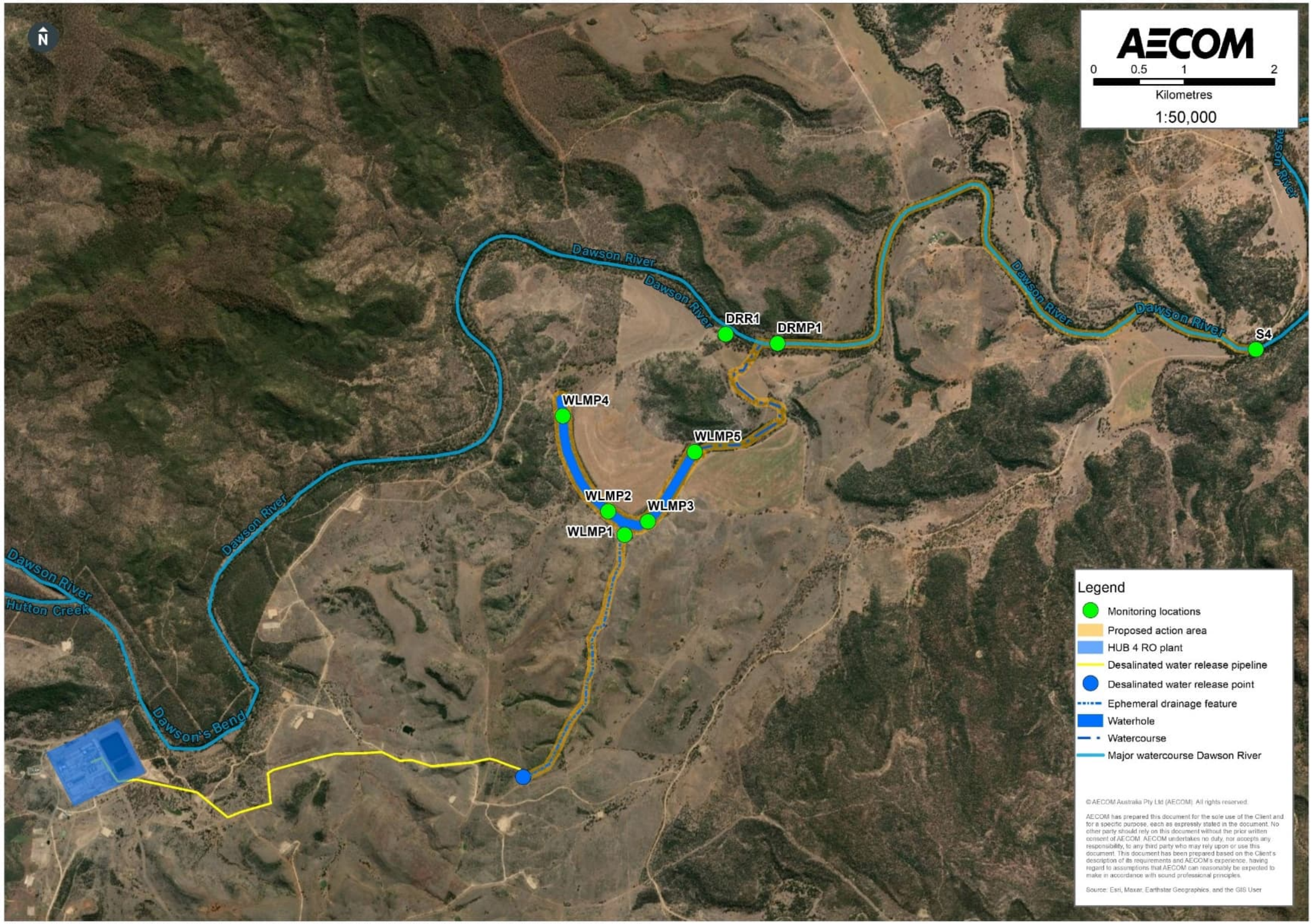


Figure 5-1 Dawson River water quality sampling locations within the Proposed Action Area

5.1 Previous Studies and surface water modelling

Desalinated water releases have occurred in the Fair View Project Area (FPA) since mid-2015 via the HCS04 ROP. To support the assessment of potential impacts to surface water hydrology and water quality and to demonstrate environmental outcomes associated with desalinated water releases a range of surface water modelling assessments have been completed since 2011. However, subsequent monitoring data has either indicated models were overly conservative or no longer required. The following historical models are considered to remain appropriate and applicable to the proposed action and are referenced to supplement the REMP data for the purposes of this assessment:

- Regional Scale Impact Assessment - Desalinated release (Santos 2012)
  - Development of a regional scale impact model using the Integrated Water Quantity and Quality Simulation Model (IQQM) developed by Queensland DES (formerly DEHP) for the Fitzroy Water Resource Operations Plan (issued in 2014 by DNRM) to assess regional scale impacts arising from the proposed desalinated water release
  - A conservative constant desalinated water release of 20 ML/day into Yebna Crossing was modelled. Model outputs were then tested against the Fitzroy Water Resources Operations Plan objectives, i.e., the relevant Water Allocation Security Objectives (WASOs) and Environmental Flow Objectives (EFOs)
  - The model found that at 20 ML/day the inter-annual variations of flows (including flood flows) in the river would be largely unaffected by the proposed desalinated water release, flooding levels would be unaffected by the desalinated water release and there would be a conservative maximum modelled change in river level at Yebna Crossing of 0.33 m as a result of predicted changes in low flows.
- Direct Toxicity Assessment - Desalinated Water Release (HALCROW 2012)
  - The results of a site-specific toxicity testing for boron indicated low toxicity, including:
    - A predicted no effect concentration (PNEC) for boron of 10.3 mg/L
    - The protective concentration for boron for 95% (PC95) of species was calculated to be 9.3 mg/L
    - Both the experimentally derived PNEC and PC95 for boron were higher than the WQO for 95% protection of aquatic species (0.37 mg/L ANZECC/ARMCANZ, 2000)
  - It is noted an update to the Direct Toxicity Assessment (DTA) was performed in 2019 (refer to AECOM 2019b below).
- Revised Boron Site-Specific Water Quality Criterion (AECOM 2019b)
  - An assessment of the 2012 DTA ecotoxicity data was undertaken to identify whether an adjustment could be made to the current water quality guideline (WQG) for boron in accordance with Australian and New Zealand Guidelines (ANZG) for Fresh and Marine Water Quality (2018) methodology (AECOM, 2019). This study determined:
    - Based on a review of the Santos ecotoxicity data against the ANZG (2018) data screening process and scoring system, the data was considered to be ‘high’ quality and suitable for guideline derivation
    - A 95 % species protection SSWQG of 2.9 mg/L was generated using high quality site-specific data via the ANZG (2018) endorsed Species Sensitivity Distribution (SSD) method
    - The SSWQG of 2.9 mg/L at 13.5 ML/day and 2.6 mg/L at 18 ML/day was different to Halcrow PC95 calculation of 9.3 mg/L because the software used by AECOM in 2019 was the most current version (Version 2.0) that incorporated latest ANZG (2018) guidance relating to fitting of the species sensitivity distribution (SSD) data. Halcrow (2012, 2013) used a Burr Type III method whereas AECOM used a log logistic fit, which resulted in the concentration differences. ANZG (2018) guidance recommends that a log logistic fit is used where the number of observations (i.e., EC/IC data) is less than eight, and a Burr Type III is used when eight or more observations are available (the model does not give the user a choice of data fitting method). A total of six observations were

available, and therefore AECOM used the log logistic fit of the data. Furthermore, AECOM used the IC/EC10 data in preference to the NOEC data in accordance with updated ANZG (2018) methodology for deriving WQGs. It should be noted that whilst Halcrow calculated a PC95 for boron of 9.3 mg/L, a predicted no effect concentration (PNEC) of 1.03 mg/L was adopted as the initial State approval limit

- The Dawson River receiving environment was considered to be classified as 'slightly to moderately disturbed' under ANZG (2018), therefore the 95% species protection was applied. As such, adoption of the 95% species protection SSWQG (2.9 mg/L) was considered appropriate as the boron site-specific water quality guideline (AECOM, 2019) for the Dawson River in accordance with ANZG Water Quality Management Framework. Refer to Sections 3.4 and Section 5.3.5.

5.2 Baseline fluvial geomorphology and hydrology

This section characterises the baseline geomorphology, flow regime and hydrology of the ephemeral drainage feature, waterhole, and Dawson River.

5.2.1 Baseline fluvial geomorphology

5.2.1.1 Drainage feature and waterhole

This section summarises the geomorphological baseline status of the drainage feature and waterhole under the current desalinated water release regime. A qualitative assessment of the drainage feature undertaken (Santos 2012) for initial State EA approvals and described the fluvial geomorphology and stream hydraulics of the drainage feature, dividing it into seven reaches (Figure 5-2).

- Reach 1 consists of the headwater section of the tributary and is characterised by a V-shaped colluvial channel in a confined valley setting. Bed material is predominantly sub-angular to angular sandstone boulders and cobbles which provide this reach a high level of resilience to erosion, while the banks are either upward fining clast supported sandstone cobbles or weathered laminar mudstones. The channel is steep, with a slope of approximately 6.6% and presents a series of boulder forced step-pools.
- Reach 2 is characterised by alternating floodplain pockets and low-grade benches along a U-shaped incised channel set in a partly confined valley setting. The bed material is similar to those in Reach 1, with the floodplain pockets providing extra resilience as they reduce flow velocities and channel erosion potential.
- Reach 3 has a distinct change in valley setting, with a wide valley bottom characterised by floodplains and terraces. The channel is incised and U-shaped with less armouring to bed and banks as in reaches 1 and 2 and the slope reduces to 2.2%. The banks of this reach are generally loose matrix supported sandstone gravels. Geomorphic features were generally limited to the rare, forced step-pool, with runs predominating.
- Reach 4 has previously incised into the valley fill and abuts the left valley margin in several locations. Sinuosity increases through this reach, and the channel is generally wide and shallow (3 meters wide and on average 0.4 m deep) with a slope of approximately 1.8%. Whilst there are patches of sandstone armouring, the majority of this reach is weathered clays.
- Reach 5 has no defined channel and is an intact valley fill. The broad valley bottom is approximately 90m across, and the valley fill extends downstream for approximately 220m. Bed material appears to be cracking clays and sandy loams.
- Reach 6 the channel becomes formalised through this reach and bed and bank material is sandy loams and cracking clays, with little to no bed armouring from sandstone cobbles as seen in the upstream reaches. Channel slope is approximately 1.4%.
- Reach 7 has no defined channel and becomes a flood-out on a broad low relief alluvial floodplain. Cattle tracks cross the floodplain and are quite deep, suggesting they are being formalised by concentrated water flow.

The assessment reported most of the drainage feature's length to be moderately stable, with the final reach having the most erosive potential. Prior to the commencement of the desalinated water releases, armouring was placed in the areas with erosive potential and at the desalinated water release point to mitigate potential erosion and sedimentation issues. Introduction of more regular water from desalinated water releases has promoted vegetative growth adjacent to the flow path, providing resistance to erosion by increasing channel roughness and by promoting the binding of soils.

REMP monitoring of the drainage feature channel has not found erosion and sediment deposition to be an issue during operation of the desalinated release. Based on this information the existing armouring of the drainage feature is expected to continue to mitigate erosion and sedimentation issues under the proposed action.

REMP monitoring of the waterhole and Dawson Riverbed and bank stability is performed twice a year as required under the State EA. Annual REMP monitoring reports for 2015 through to 2021 (presented in Appendix F) have not identified bed or bank stability issues resulting from desalinated water releases as summarised in Table 5-1 indicating stable conditions.

Table 5-1 Waterhole and Dawson River REMP qualitative monitoring for bank stability, bed stability and substrate diversity

Habitat Attribute	2015	2016	2017	2018	2019	2020	2021
Waterhole							
Bank Stability	M / M	H /H	M / M	M / M	M / M	M / M	M-H
Bed Stability	H / H	H / H	H / H	H / H	H / H	L-M / L-M	M
Substrate Diversity	L / L	-	L / L	L / L	L / L	L / L	L-M
Dawson River							
Bank Stability	M / M	M / M	M / M	M / M	M / M	M / L-M	L-M
Bed Stability	L / L	L-M / M	L / L	L / L	L / L	L / L-M	M
Substrate Diversity	H / -	-	H / H	H / H	M / M	M /M	M-H

Notes
Post wet season / Pre wet season
H = High; M = Moderate; L = Low
Where a single entry is provided, only one assessment was conducted in that year
Assessment provides a single value pooled from:
- WLMP1, WLMP4 and WLMP5 in the waterhole
- DRR1, DRMP1 and S4 in the Dawson River

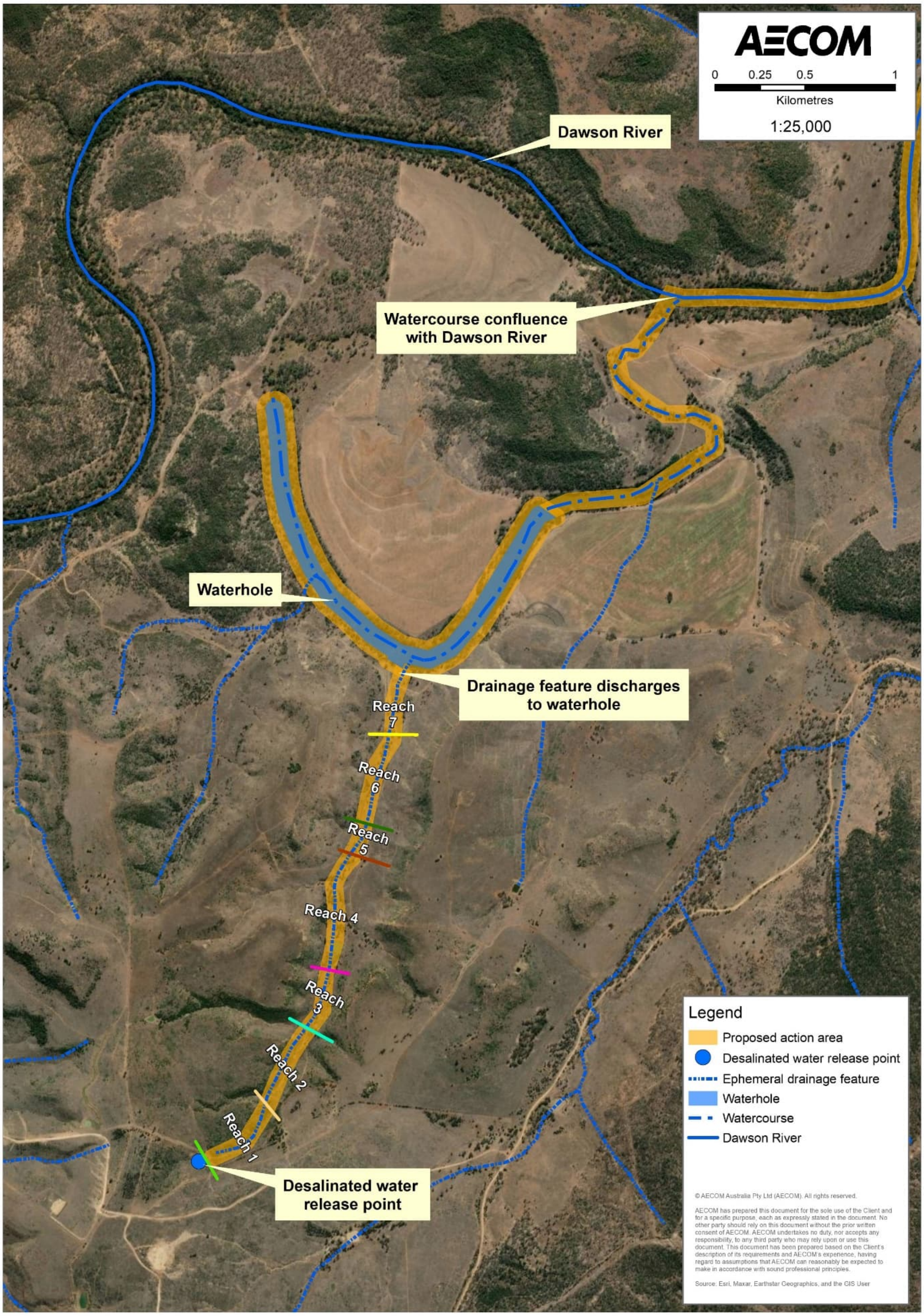


Figure 5-2 Drainage feature reaches

5.2.1.2 Dawson River

Within the proposed action area, the Dawson River is relatively narrow for much of its length, mostly confined by adjacent uplands (rises and low hills) formed on outcropping siltstones and sandstones of the Evergreen Formation (Forbes 1968), with limited development of a floodplain. The river channel contains mobile sand and gravel alluvium, interspersed with loose siltstone boulders and areas of solid outcropping bedrock (Santos 2012, AECOM 2016).

Upstream of the proposed action area the Dawson River incises the underlying Lower Precipice Sandstone aquifer and receives discharge from this aquifer, which has a head of pressure some 20 m above the bed level. This means that in this particular reach the Dawson River is a gaining stream (Figure 4-26). Numerous springs present on or near the banks of the river and discharge into the river where the Precipice Sandstone piezometric surface is above ground level e.g., the Yebna 2 spring complex (Section 4.1.2.3). Most inflow from the Precipice Sandstone occurs below bed level (refer to Figure 4-26). As such the perennial base-flow of the Dawson River in the proposed action area is derived from the Precipice Sandstone.

At its confluence with the waterhole discharge point, the Dawson River is shallow, approximately 10 m wide and characterised by constricted flow sections, frequent occurrences of in-stream woody debris as observed in Figure 5-3.

Figure 5-3 2021 post wet season photos of DRMP1 viewing downstream (left) and upstream (right)

Downstream of Yebna Crossing, the Dawson River enters a much broader, extensively cleared alluvial plain, with floodplains of clay loam extend landward from the silty sand to silty clay banks of the river. The main channel becomes more laterally active with frequent channel cut offs and anabranches noted.

5.2.2 Baseline hydrology

Desalinated water releases started in July 2015 (Figure 2-3). Existing desalinated water release conditions have been as follows (refer to Section 2.0, Table 2-1):

- The release of desalinated water has occurred intermittently since 2015 depending on the operation of the DWB pond decanting procedures (Figure 2-3) and has occurred between 87 days (2016) to 156 days (2020) depending on the year (Table 2-1). Under the current revised desalinated water management procedures implemented during 2021 there were 95 release days over the year.
- The desalinated water release has generally occurred at a rate less than 13.5 ML/day, with a median of 13.4 ML/day and an average of 12.7 ML/day when releases occur.
- Notwithstanding, three instances of desalinated water release have occurred at the maximum authorised rate of 18 ML/day occurred in July 2016, February 2017 and August 2022 (Figure 2-3 and Figure 5-11).

5.2.2.1 Drainage feature

5.2.2.1.1 Overview

The drainage feature from its source to the point at which it enters the waterhole is a comparatively small catchment of 391 ha draining only the immediately adjacent hillslopes. The drainage feature is ephemeral, identified as a first order stream[22].

The assumed hydrological characteristics of the drainage feature upstream of the waterhole, prior to the commencement of treated (desalinated) water releases in 2015, is summarised as follows:

- The geometry of the ephemeral drainage path comprises a narrow gully, of limited width (approx. 1 m), with an approximate invert gradient of 2%. The total catchment area reporting to the drainage path (upstream of the waterhole) is approximately 396 ha.
- The drainage feature is a first order stream, and does not receive runoff from other drainage paths, creeks, or waterways.
- Limited vegetation is present within the catchment, or adjacent to the drainage path, associated with historical agricultural and forestry activities.

Based upon the described characteristics, the drainage path can be characterised as an ephemeral stream, with flow expected in response to rainfall events exceeding available catchment losses, with negligible flow during clear sky conditions.

5.2.2.1.2 Fine scale mapping

A finer scale of mapping exercise was undertaken for initial State EA approvals (Alluvium 2012); the mapping identifying seven (7) first order ephemeral minor tributaries draining into the drainage feature, with further minor drainage lines and overland flow contributed from the surrounding hillslopes.

Using the median and maximum daily release rates of 7.5 ML/day and 18 ML/day, respectively, an assessment of changes to potential flow rate and channel (water depths) within the drainage feature reaches (refer to Section 5.2.1.1 for reach descriptions).

Table 5-2 presents the modelled increase in peak flow rates in the drainage feature attributable to desalinated water release as a proportion of design storm flows. The median (7.5 ML/day) and maximum (18 ML/day) daily release rates were predicted to result in only a very minor increase to the peak flow rates from the drainage feature occurring during design storm events.

Table 5-2 Percentage flow increase to peak of design storm events (Santos 2012)

Design Storm Event	Peak Flow (m^3/s)	% Peak Flow Increases per Proposed Release Rate	
		+7.5 ML/day (median)	+ 18 ML/day (maximum)
2 year	12.37	0.7%	1.7%
5 year	15.78	0.6%	1.3%
10 year	17.92	0.5%	1.2%

[22] Stream ordering provides an indication of the relative size of a watercourse within a climatic and geomorphic setting. A classification of Strahler stream order is included in the DERM (2011) Queensland watercourse digital data. Strahler's (1952) stream order system is a simple method of classifying stream segments based on the number and magnitude of tributaries upstream. A stream with no tributaries (headwater stream) is considered a first order stream. A segment downstream of the confluence of two first order streams is a second order stream. Thus, an n^{th} order stream is always located downstream of the confluence of two $(n-1)^{th}$ order streams (Strahler, 1952).

Figure 5-4 Historical imagery 1997 of Drainage Feature and Waterhole (DNRM - QImagery, 1997)

Modelling for the drainage feature reaches outside storm events predicted water depths within the drainage feature (between point of release to the waterhole) to vary between 0.02 and 0.12 m at a 7.5 ML/day release rate) and between 0.03 and 0.16 m at an 18 ML/day release rate. Modelled data indicated these increases would be observed in the upper and middle reaches of the drainage feature. At the discharge point of the drainage feature to the waterhole, water depths in the drainage feature were predicted to increase between 0.03 m and 0.04 m at the respective release rates.

The modelling for the drainage feature was based on the continuous release of 7.5 and 18 ML/day. As described in Section 2.2.3, to date, the GLNG Project desalinated releases have been periodic, and generally at around 13.5 ML/day. Observations made during REMP monitoring have indicated the change in water depths in the drainage feature, during periods of release, are consistent with the model predictions.

5.2.2.2 Waterhole

5.2.2.2.1 Overview

The waterhole is generally considered ephemeral, although observations made following the 2011-12 wet season noted it was almost at full capacity. The waterhole, when at full capacity, has a water level of approximately 249.6 m AHD[23] and is approximately 32.5 ha in area (refer to Section 4.2.3.3). The drainage feature enters the waterhole approximately half-way along its length prior to waterhole discharging to the Dawson River.

The topography surrounding the waterhole is shown in Figure 5-6 reflecting LiDAR data captured by Aerometrix Ltd between December 2020 and January 2021.

Desalinated water releases indicate a measured increase in water depth within the waterhole at WLMP1 from before the start of desalinated water releases in 2015 was approximately 1.0 m. Since the start of desalinated water releases measured water depth has been maintained at a depth of approx. 1 m with a variability ranging between +0.4 m and 0.5 m depending on desalinated water release rate between 13.5 ML/day and 18 ML/day and duration between release events (Figure 5-5 and Figure 5-11).

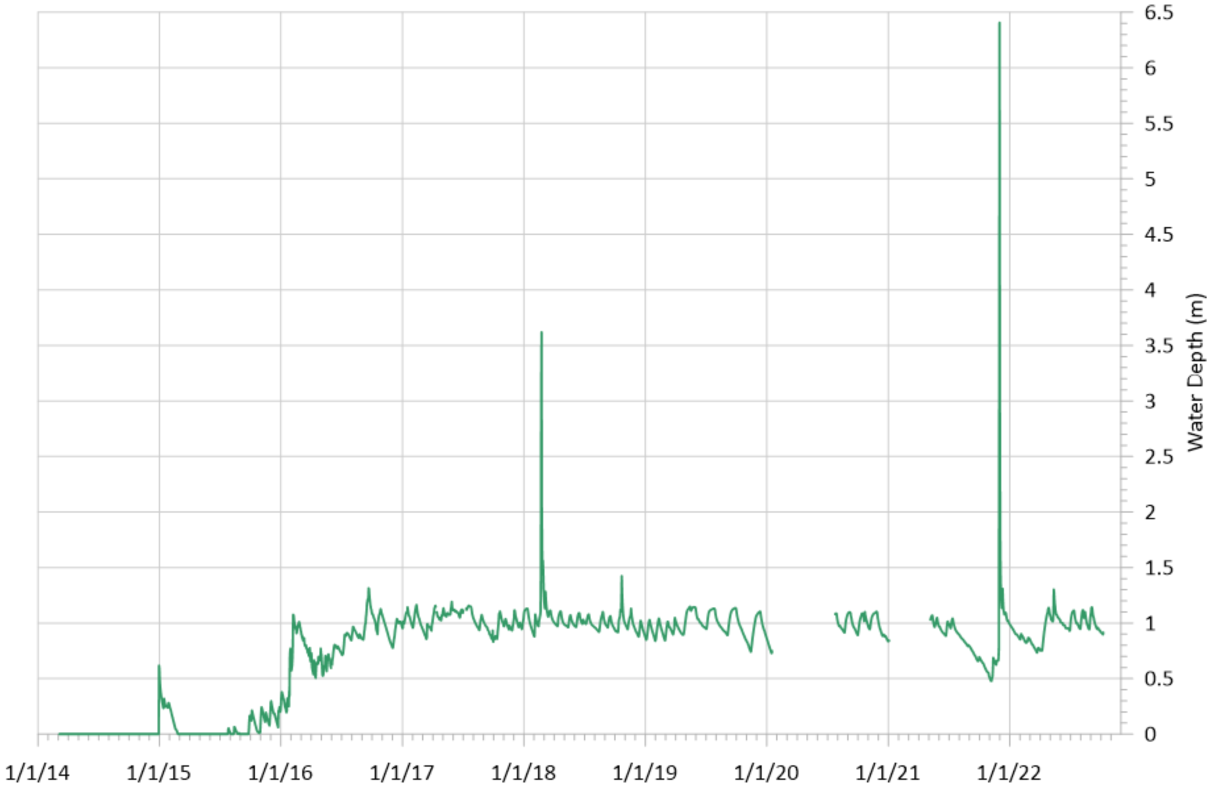


Figure 5-5 Waterhole water levels (WLMP1)

It is noted that Figure 5-5 includes a peak increase of over 3.4 m in February 2018 (278 mm monthly rainfall[24]) and November 2021 (263 mm monthly rainfall) that coincides with high flow events in the Dawson River**.** Whilst the observed increase coincides with a significant rain event of 159.8 mm on 21st February and a Dawson River flood event, the magnitude of the measured increase within the waterhole for both events is considered a gauging error and not actual water depth over the waterhole.

[24] Injune PO Station No. 43015 located 55 km west of the proposed action area

During normal flow conditions both prior to the start and following desalinated water releases, the overflow level from the waterhole to the Dawson River is approximately 249.6 m AHD (Section 4.2.3.3), whilst the stage height of the Dawson River is approximately 9 m lower at 240.5 m AHD (after Greenspan, 2012).

During flood conditions, hydraulic connection from the Dawson River to the waterhole may occur via:

- Upstream of a topographic constriction of the Dawson River floodplain, at the north-western limit of the waterhole, at an approximate level of 256.6 m AHD.
- Downstream of a topographic constriction of the Dawson River floodplain, at the north-eastern limit of the waterhole, at an approximate level of 254.8 m AHD.
- Via the waterhole outlet, at an elevation of 249.6±0.1 m AHD.

This is important to understand as flood flows from the Dawson River may create a backwater effect due to the floodplain constriction indicated in Figure 5-6. This is potentially the cause of the higher water depths at WLMP1 observed in Figure 5-5noting actual indicated flow depths may be low reliability data. These flood levels are approximately 15.5 m to 16.5 m above the baseflow water depth and there is no evidence that this has occurred since S4 monitoring commenced in 2012. As discussed in Section 4.2.3.3, inflow from the Dawson River to the waterhole via the downstream watercourse only occurs if river height exceeds 249.6±0.1 m AHD, 9 m above baseflow water depths.

Basin level flood studies, obtained via the Queensland FloodCheck website, suggest this connectivity may be established during a 1% AEP flood event, as shown in Figure 5-7.

Further, the connectivity in flood conditions may provide an indication as to hydrodynamics which contributed to the formation of the waterhole.

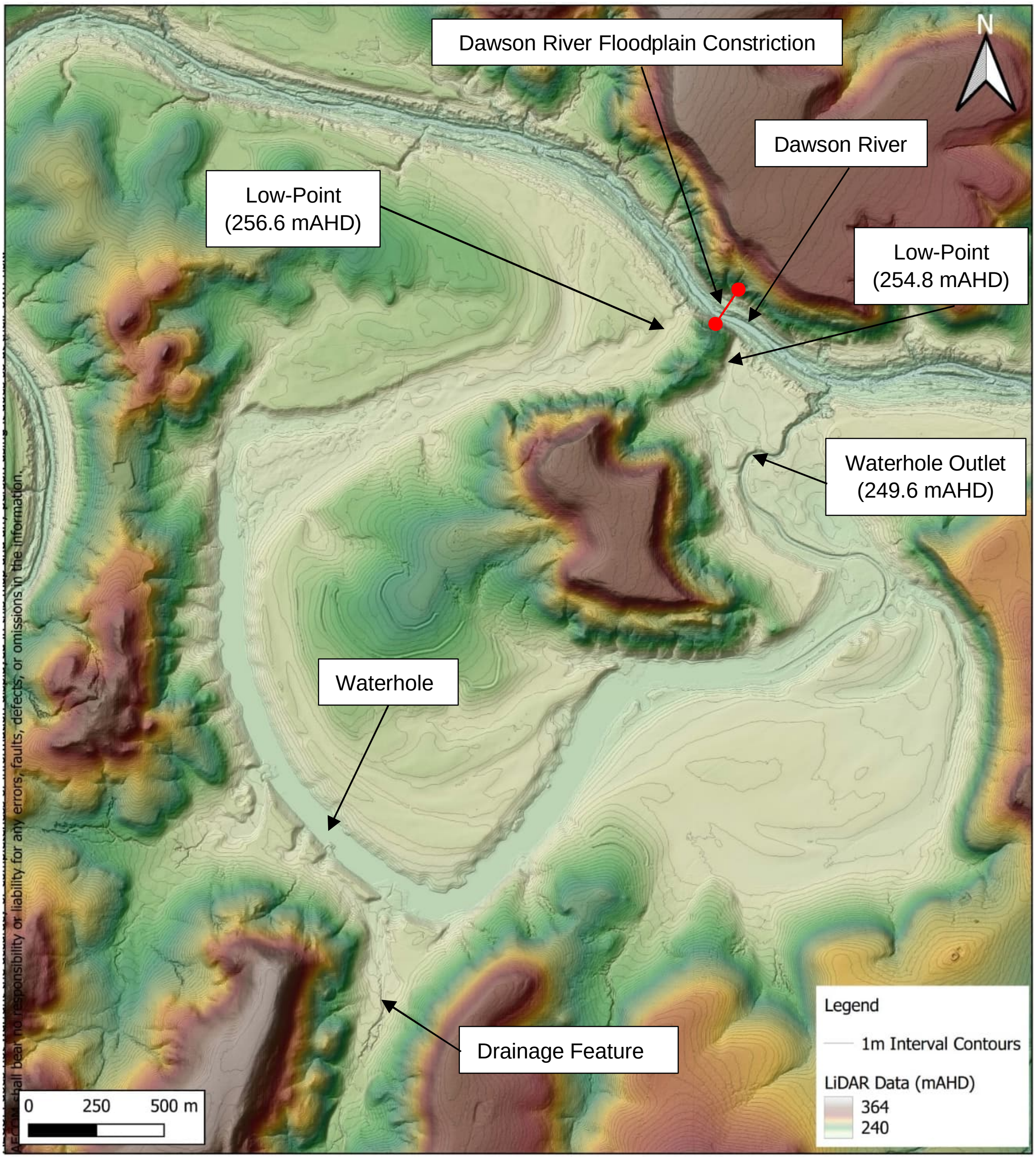


Figure 5-6 Waterhole LiDAR topography – (Aerometrex Ltd – December 2020)

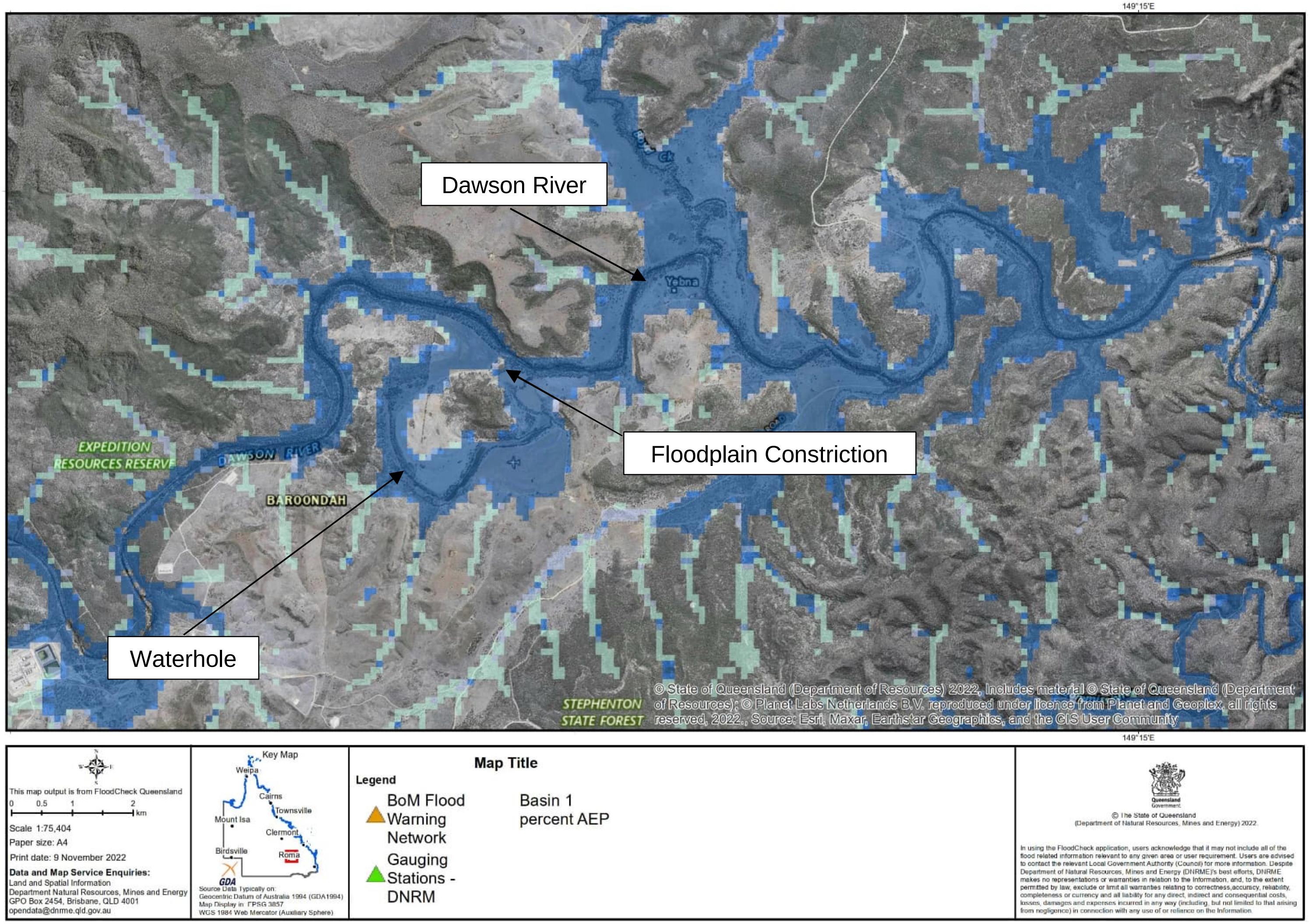


Figure 5-7 Basin flood study – 1% AEP – Queensland FloodCheck

5.2.2.2.2 Waterhole spill point

The waterhole spill point is located towards the north-east limit of the outlet watercourse at the location of an at-grade access track crossing linking the landholder's paddocks (refer Figure 5-8). Flow from the waterhole is conveyed via the outlet watercourse to the Dawson River. The access track topography forms an informal weir profile, regulating potential discharges from the waterhole. The access track cross section based on LiDAR data is shown in Figure 5-9**.**

Figure 5-8 Waterhole Outlet – Access Track – during discharge (left) and during no discharge (right)- Photo

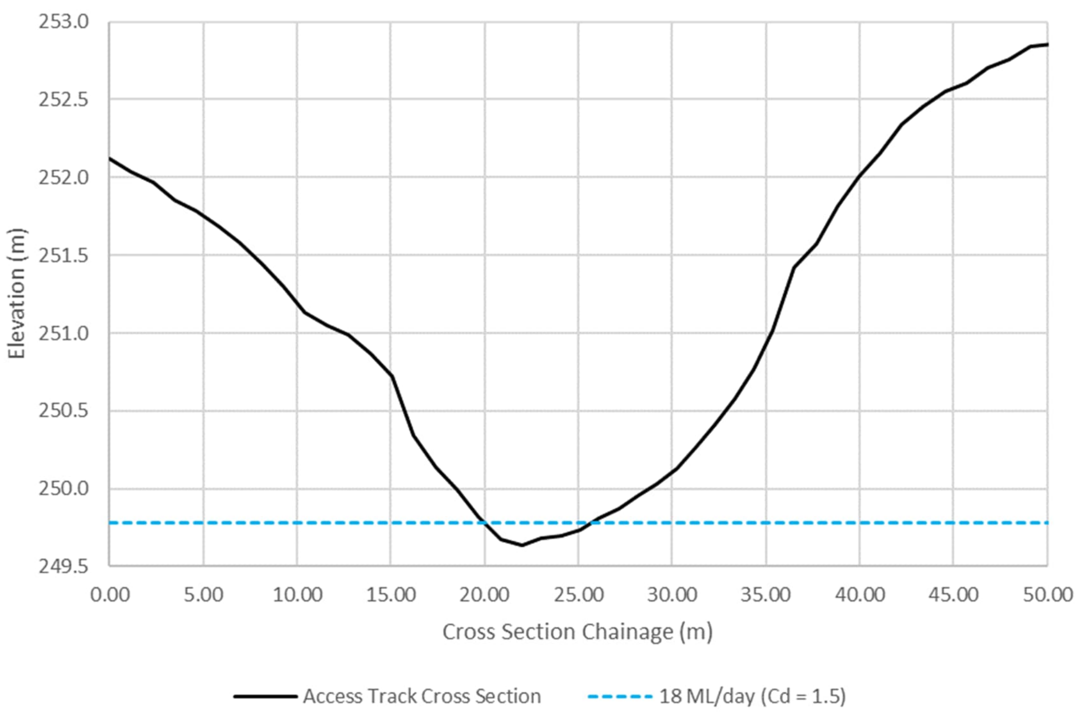


Figure 5-9 Waterhole outlet watercourse – access track – cross section and weir flow estimate (at 18 ML/day)

Estimation of the potential flow characteristics at the waterhole spill point in the watercourse was completed utilising a broad crested weir equation, utilising:

- Cross section data sampled from Aerometrix LiDAR data (2020)
- Assumed broad crested weir coefficient of discharge (C_D) of 1.5.

The flow characteristics were developed assuming the upstream outlet watercourse and waterhole are at a steady-state condition, ignoring potential upstream losses, such as evapotranspiration and infiltration (as a conservative assumption). Concurrent hydrological inflows were not included within this estimation, noting that potential hydrological inflows are likely to exceed the release rate (18 ML/day) by orders of magnitude.

The calculated flow characteristics at the spill point within the outlet watercourse are listed in Table 5-3.

Table 5-3 Waterhole spill point flow estimate (18 ML/day)

Description	Value
Minimum elevation of outlet	249.64 mAHD
Outlet flow rate	18 ML/day
Estimated Flow Level	249.78 mAHD
Modelled water depth of flow	0.14 m
Width of Flow	6.4 m
Average Velocity	0.46 m/s

The flow estimate, and photographic record of the outlet watercourse spill point, suggest that flows from the waterhole are of limited stage height and velocity in the absence of other waterhole catchment inflows.

5.2.2.3 Dawson River hydrology

The Dawson River within the proposed action area extends from the confluence with the outlet watercourse to monitoring location S4 at the downstream point of Yebna Crossing as indicated in Figure 5-1. The Dawson River within the proposed action area is perennial with baseflow fed by spring flow from the Precipice Sandstone (located upstream of the proposed action area) as discussed in Section 4.2.4.

5.2.2.3.1 Overview

Baseline hydrology studies have been completed to determine the natural surface water flow of the Dawson River to assess the flow seasonality, variability, volume, and event duration. Gauging of water depth and flow has occurred at monitoring location S4 on the Dawson River (Figure 5-10) prior to and following the start of desalinated releases in 2015.

Data for the S4 gauging station at the downstream limit of the proposed action area indicates:

- Baseflow at the S4 gauging station ranges between approximately 20 ML/day to 30 ML/day over the 2013 to 2021 period (Figure 5-10and Figure 5-11), maintained by spring flow and baseflow from the Precipice Sandstone (Section 4.2)
- Based on the calculated flow duration curve for the S4 August 2012 to July 2015 data (Figure 5-12), 80% of flow was recorded below 40 ML/day and 90% of flow was recorded below 50 ML/day
- The Dawson River rises rapidly in response to rain events, with flood flows travelling at high velocity even in areas of moderately flat relief
- Anecdotal observations indicate debris is often found in trees many metres above normal river level, consistent with the higher flow depths evident in S4 gauging data
- Inundation of Yebna Crossing has not been observed during baseflow conditions since the start of desalinated water discharges in 2015

- Under higher flow events, increases in river depth and river discharge as a result of the desalinated water releases cannot be distinguished at the S4 gauging station (Figure 5-10 and Figure 5-11).

Data gaps visible in the hydrographs for the WLMP1 and S4 gauging locations reflect periods of station damage following flood conditions. During February 2022 both gauges were flood damaged and no gauge data has been available since that time. Santos is currently working to reinstate the gauges recording equipment at a higher elevation to reduce outages.

Detailed hydrograph of actual gauged water level changes under 13.5 ML/day and 18 ML/day are presented in Section 5.2.2.3.3**.** Measured water depths during the August to December 2020 period (Figure 5-14) display the measured water depth increase at 13.5 ML/day of desalinated water release rates. Measured water depths during the January to February 2017 period (Figure 5-15) display the measured water depth increase at 18 ML/day of desalinated water release rates.

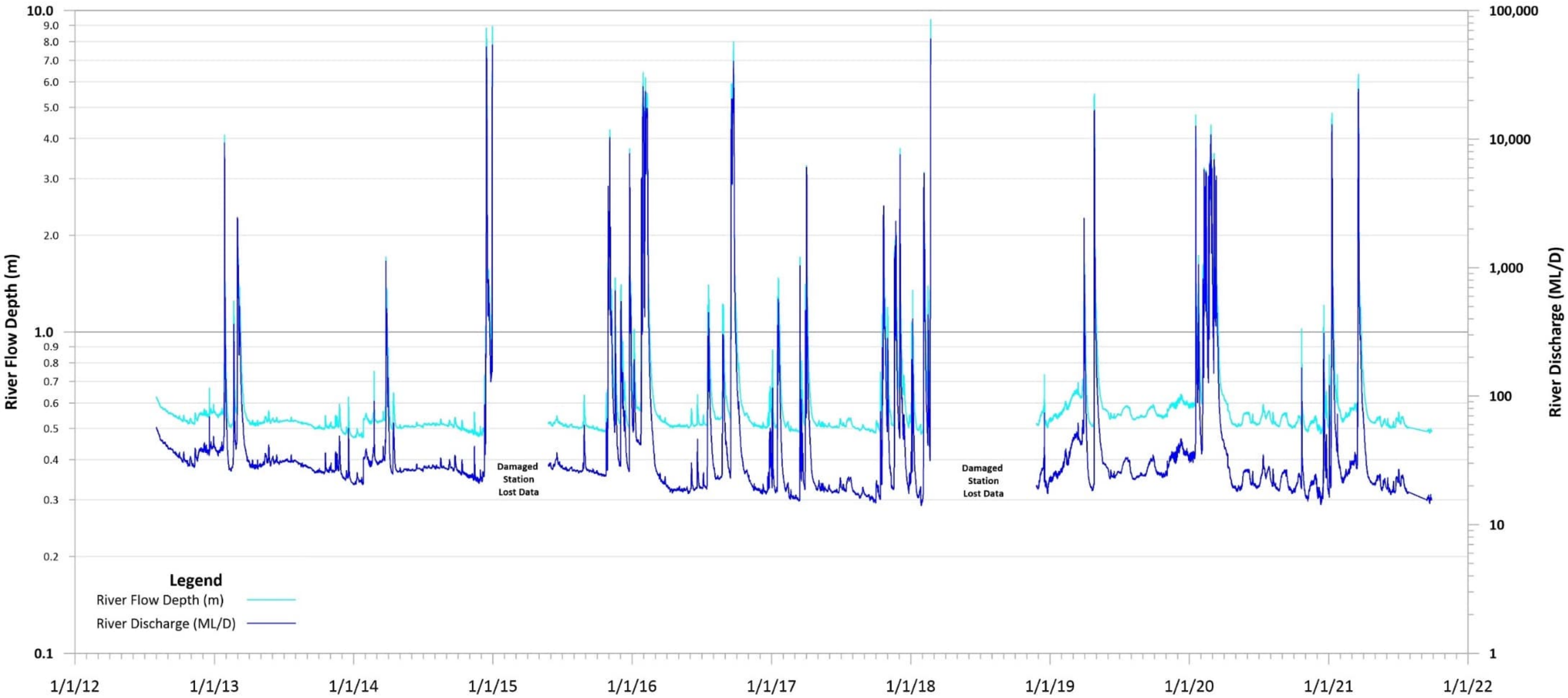


Figure 5-10 **Dawson River Hydrograph – local gauging station S4 (Source: Santos - Aug 2012 - Oct 2021 – S4 station Damaged in flood and in progress of replacement)**

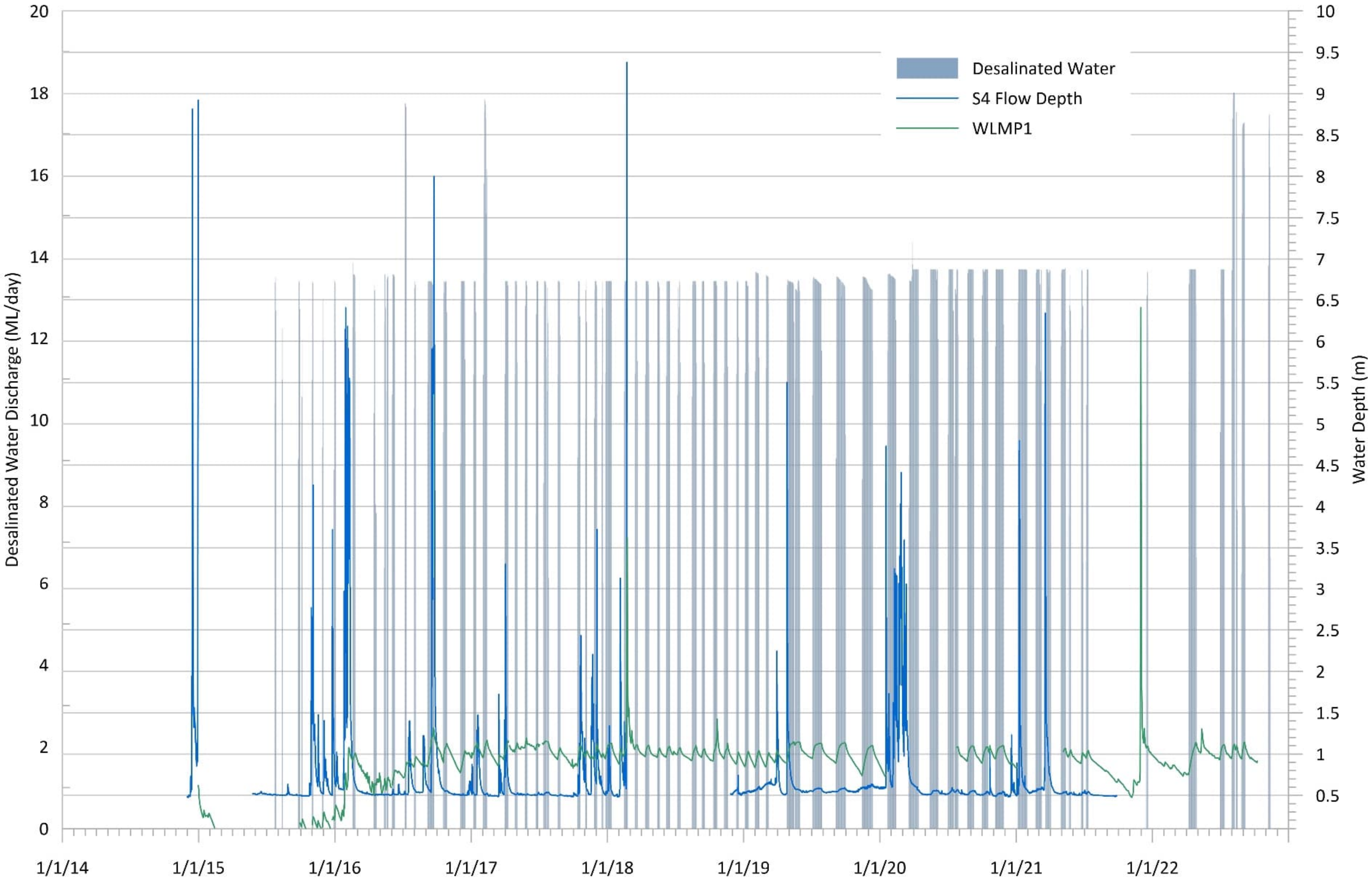


Figure 5-11 **2014 to 2022 Dawson River hydrograph – local gauging station S4 (Depth only), Waterhole Water levels (WLMP1) and desalinated water release events**

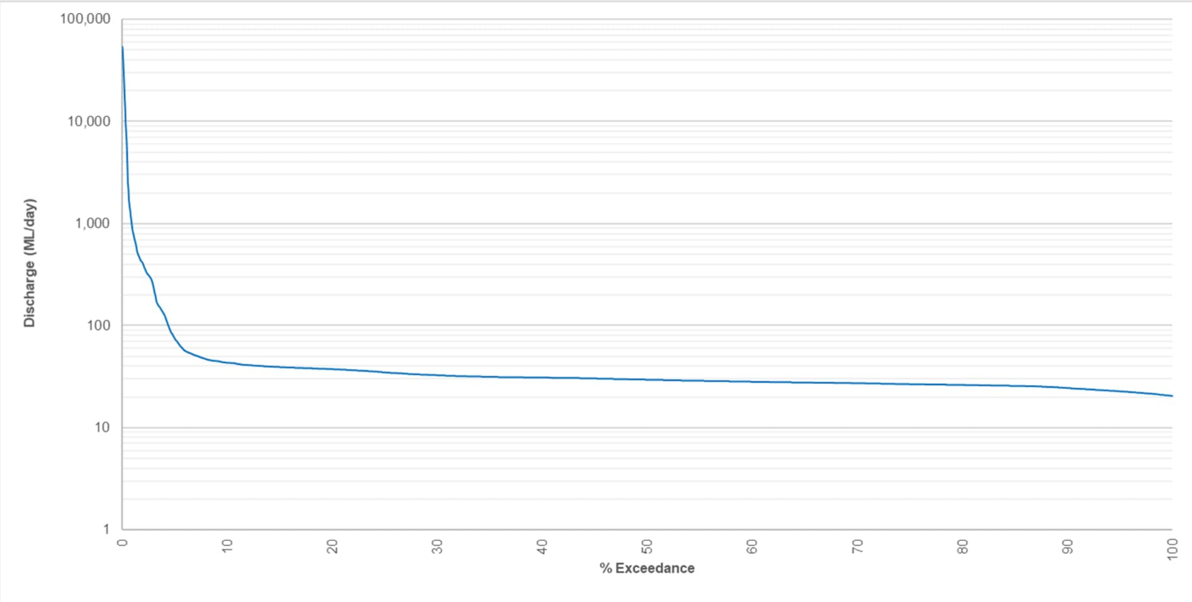


Figure 5-12 **Dawson River flow duration curve local gauging station S4 (Aug 2012 – July 2015)**

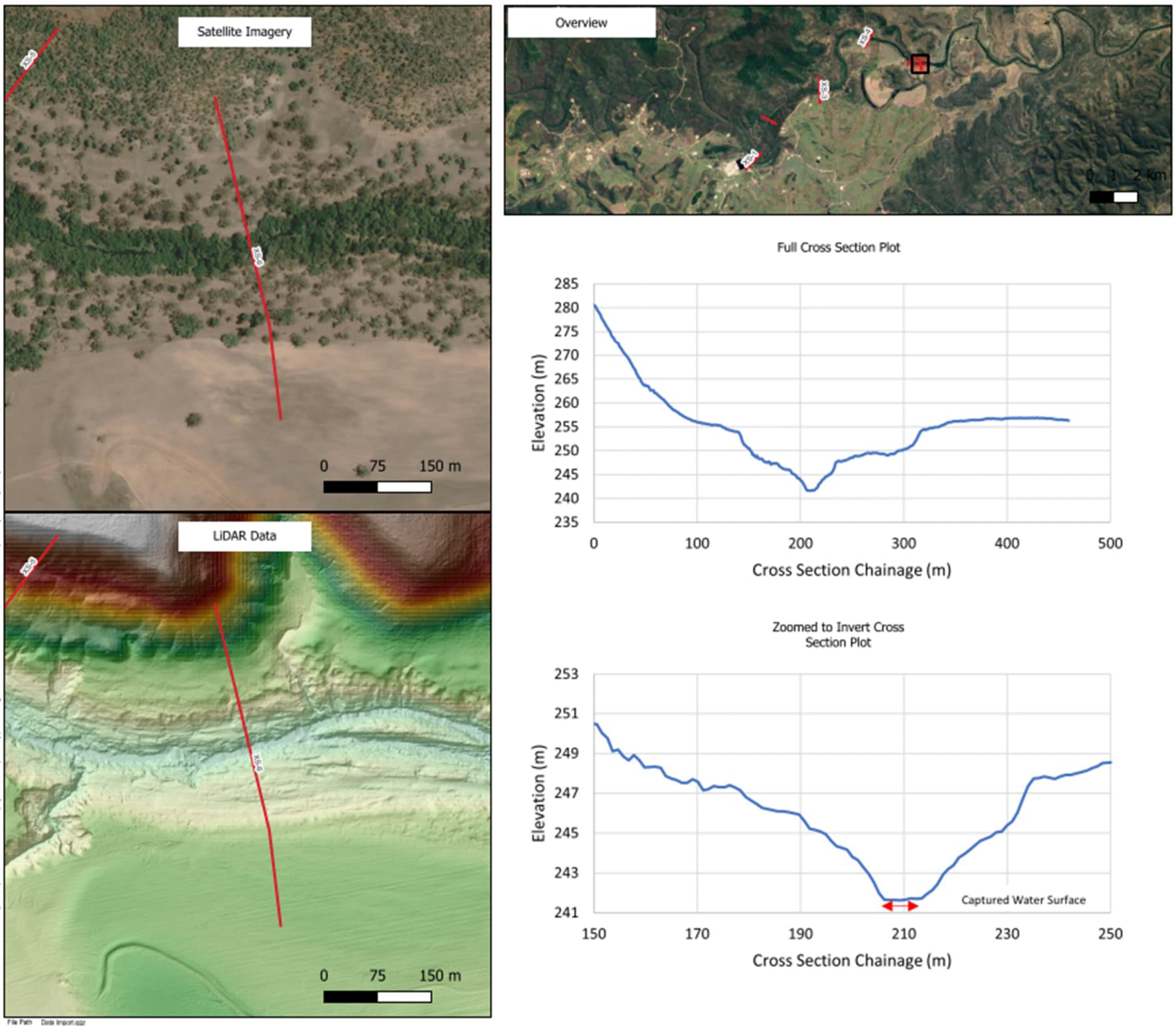


Figure 5-13 **Dawson River cross section – downstream of Waterhole and Dawson River confluence point**

5.2.2.3.2 DRMP1 cross section analysis

To confirm the analyses completed in 2012 modelling, a brief review of the discharge properties of the Dawson River was completed during the preparation of this PD. The review involved the analysis of potential flow characteristics, based upon a cross section of the Dawson River, located at DRMP1 immediately downstream of the confluence point with the outlet watercourse from the waterhole.

The cross-section location and profile are shown in Figure 5-13, and are based upon the Aerometrex Ltd LiDAR data captured in December 2020 to January 2021.

Flow at the cross section was analysed utilising a uniform flow calculation (Manning's calculation) utilising the assumptions listed in Table 5-4.

Table 5-4 Dawson River flow calculation assumptions

Aspect	Assumption
Calculation Method	Uniform Flow Calculation
Manning's 'n' Roughness	0.03
Dawson River Invert Gradient	0.136%

The magnitude of Dawson River flow depth and velocity changes with and without assumed water release at the 18 ML/day rate are listed in Table 5-5.

Table 5-5 Inferred incremental increase water depth downstream of waterhole and Dawson River confluence due to an 18 ML/day release rate of desalinated water

Time Exceeded*	Baseflow (ML/day)	River Level (m AHD)	Baseflow and Treated Release (ML/day)	River Level (m AHD)	Approximate Increase in water depth (m)
50%	20	241.78	38	241.84	0.06
10%	45	241.86	63	241.89	0.04
5%	70	241.91	88	241.94	0.03
2%	900	242.65	918	242.66	0.01
*Baseflow estimates have been adopted based on the Flow Duration curve for the S4 gauge, shown in Figure 5-12					

Table 5-6 Inferred incremental increase in water velocity downstream of waterhole and Dawson River confluence due to an 18 ML/day release rate of desalinated water

Time Exceeded*	Baseflow (ML/day)	Average Velocity (m/s)	Baseflow and Treated Release (ML/day)	Average Velocity (m/s)	Approximate Increase in velocity (m/s)
50%	20	0.28	38	0.35	0.07
10%	45	0.37	63	0.42	0.05
5%	70	0.43	88	0.47	0.04
2%	900	1.02	918	1.03	0.01
*Baseflow estimates have been adopted based on the Flow Duration curve for the S4 gauge, shown in Figure 5-12					

The calculations, although simply derived, provide an indication of the potential water depth and velocity increases immediately downstream of the confluence point of the waterhole outlet and Dawson River during an 18 ML/day release of desalinated water. The calculations indicate the magnitude of increase in Dawson River water depth due to the desalinated water releases is approximately 0.01 m – 0.06 m and velocity is approximately 0.01 to 0.07 m/s depending on river discharge/flood conditions. This is consistent with actual water depth measurements at Yebna crossing discussed in Section 5.2.2.3.3.

It is noted that the incremental increase during flooding conditions within the Dawson River, due to the desalinated release rate, is negligible and imperceptible within the measured data.

5.2.2.3.3 Observed afflux at S4 gauge

Interrogation of available stage water level and rating curve data for the S4 gauge location was completed to estimate the potential increases in Dawson River flow, subject to the maximum release potential of 18 ML/day. The interrogation involved both the inspection of observed increases at S4 due to historical releases at the 13.5 ML/day and 18 ML/day rates, as well as theoretical consideration of the gauge rating curve.

Measured water level increases during periods of desalinated water release are shown graphically in Figure 5-14 for 13.5 ML/day desalinated water releases under baseflow conditions and Figure 5-15 for an 18 ML/day desalinated water under baseflow conditions in a drier than normal year (2017). The measured data indicates the following increases in water level:

- The measured increase in water at S4, based upon multiple periods of release at 13.5 ML/day between August and December 2020 under baseflow conditions is approximately 0.05 m (5 cm).
- The increase in water depth at S4, based upon a singular release at 18 ML/day under the falling stage and then baseflow conditions in February 2017, is approximately 0.03m (3 cm). It is noted that this stage increase occurred during the recession period of a rainfall event, such that the magnitude of stage increase is partially obscured.

In both cases presented in Figure 5-14 and Figure 5-15 observed increases in water depth at S4 following the start of desalinated water releases occurs slowly over a number of days as the upstream waterhole gradually fills and starts to spill. Initial water level increases in the Dawson River at S4 are not observable for between two to three days, then water level gradually increases to maximum over a duration of between nine to ten days.

Measured water level increases in the waterhole and Dawson River in response to various rainfall within the catchment are significantly greater and more rapid, occurring typically within over the same day as the rainfall event.

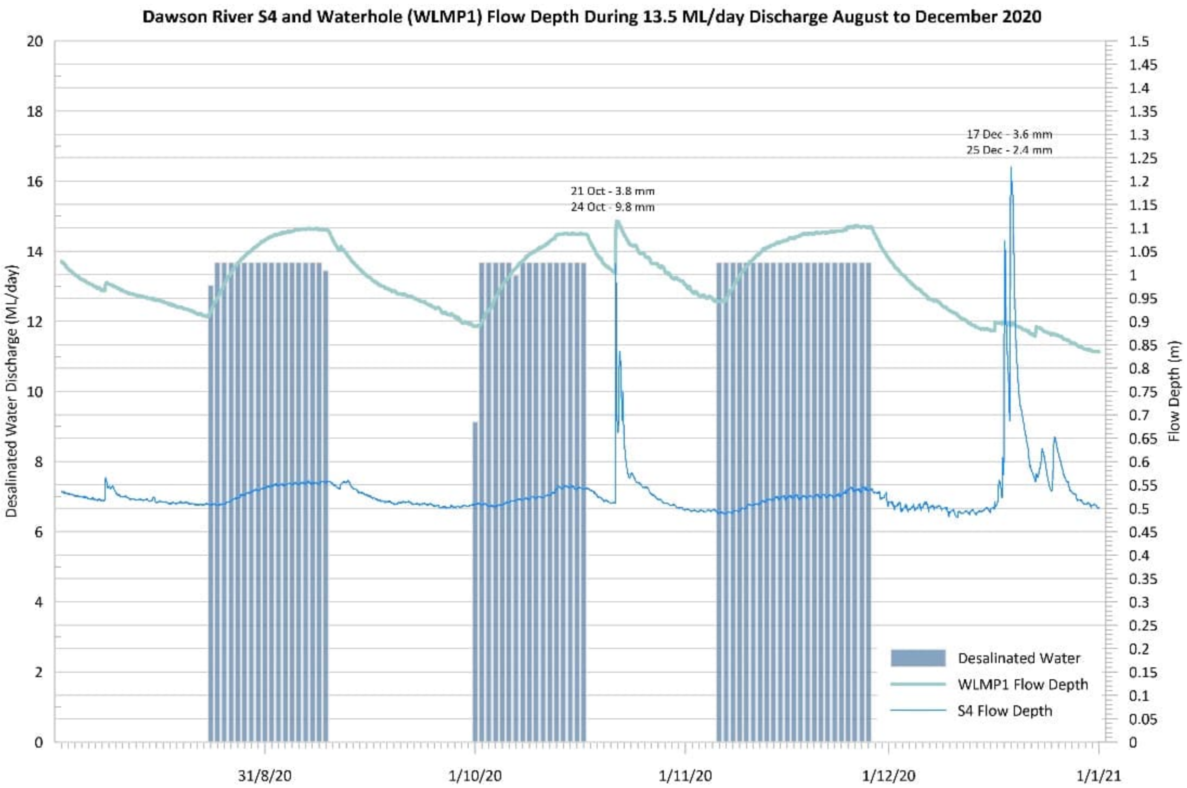


Figure 5-14 Measured water level increases at a13.5 ML/day release rate at WLMP1 and S4 (rainfall – Injune PO)

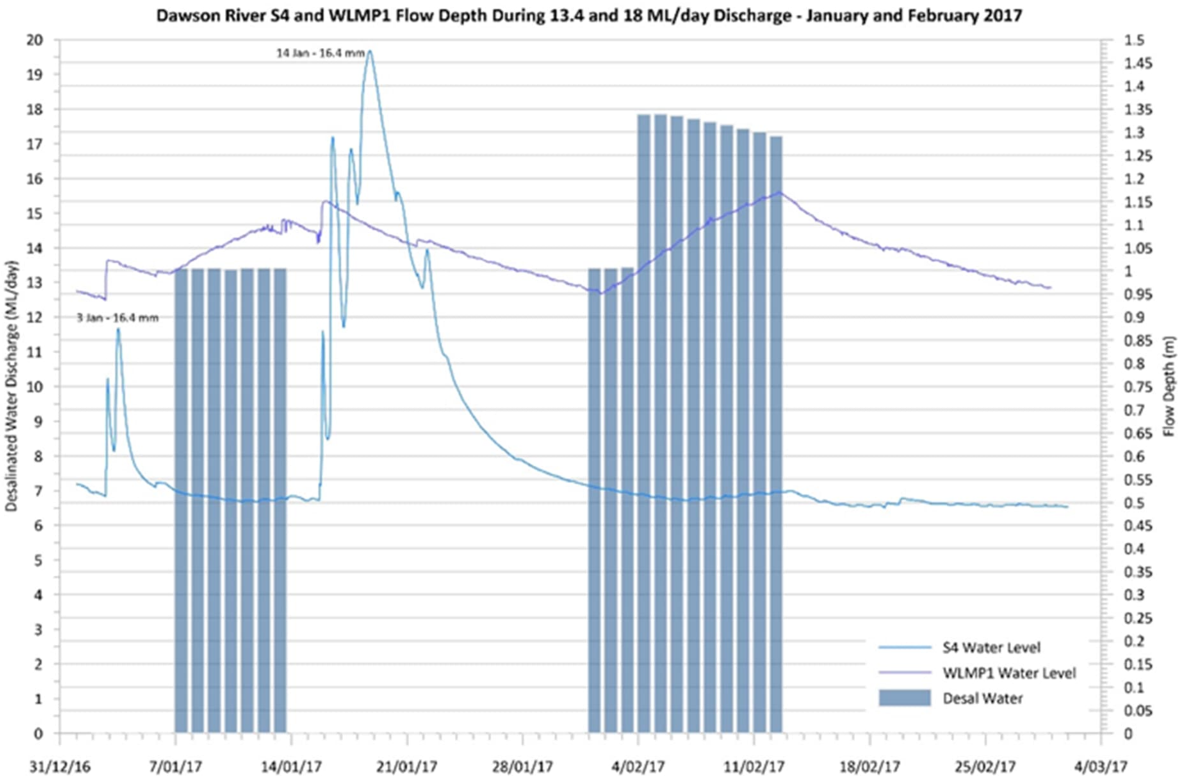


Figure 5-15 **Measured water level increases at an 18 ML/day release rate at WLMP1 and S4 (rainfall – Injune PO)**

Consideration of potential increases, utilising the available S4 gauge rating curve data was also completed. The inferred gauge rating curve is shown in Figure 5-16.

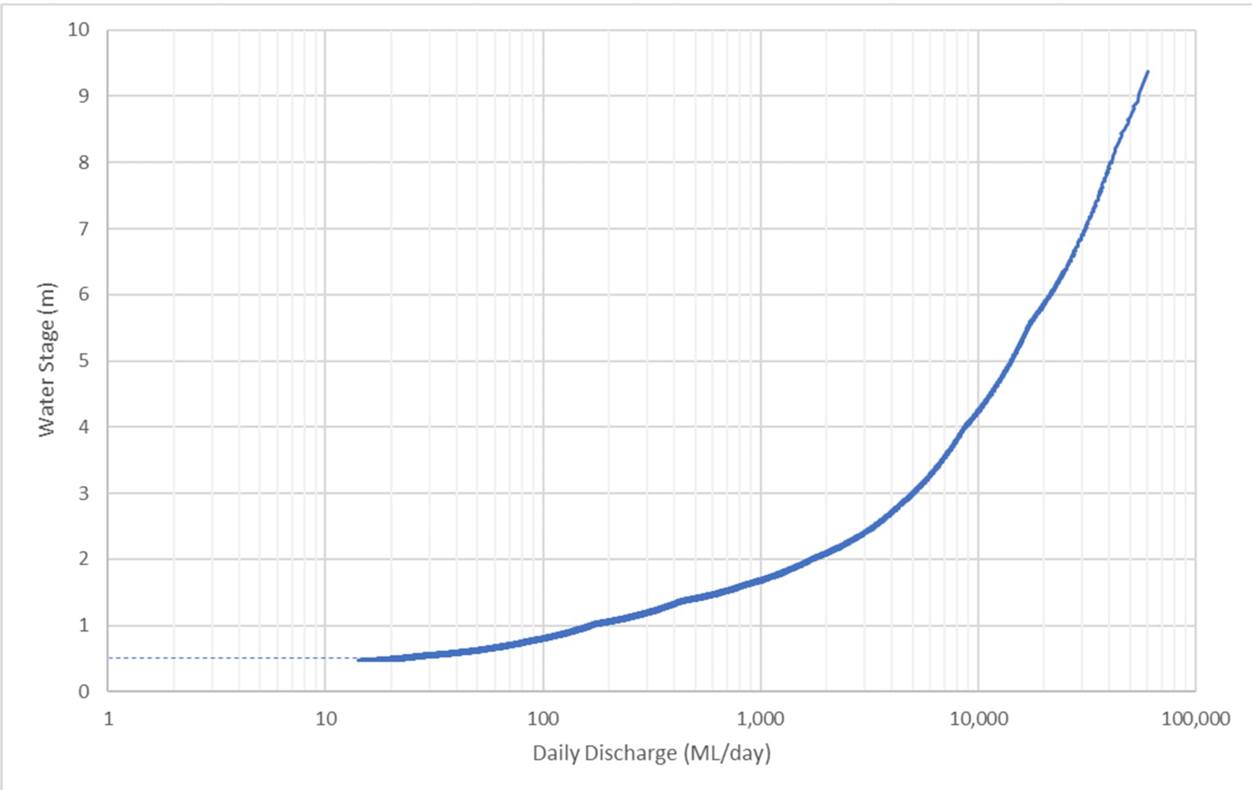


Figure 5-16 **S4 rating curve**

Calculated changes in water depth at S4 based on the assumptions in Section 5.2.2.3.2 are listed in Table 5-7.

Table 5-7 Inferred incremental increase at S4 gauge due to release rate (18 ML/day)

Time Exceeded*	Baseflow (ML/day)	S4 Gauge Level (m)	Baseflow and Treated Release (ML/day)	S4 Gauge Level (m)	Approximate Increase in Water Depth (m)
50%	20	0.50	38	0.57	0.07
10%	45	0.62	63	0.68	0.06
5%	70	0.71	88	0.77	0.06
2%	900	1.63	918	1.64	0.01
*Baseflow estimates have been adopted based on the Flow Duration curve for the S4 gauge, shown in Figure 5-12					

The analysis shows that the increase in water depth at the S4 gauge are expected to be 0.07 m (7 cm); consistent with measured data that indicate no more than a 0.05 m increase.

The calculated and measured increases in water depth are generally in agreement, noting that the measured increases at S4 include losses from evaporation, seepage and a degree of reach storage that are unaccounted in calculated increases.

Accordingly, the potential increase in flow depths at S4 during desalinated water releases (and by default the proposed action) is considered low. Further, the increase in flow depth during periods of significant Dawson River flow, such as flooding conditions, is considered negligible, and is imperceptible compared to flood water depth conditions.

5.2.2.4 Summary of baseline hydrology

A summary of the potential project impact in frequency and water level terms is listed in Table 5-8.

Table 5-8 Summary of potential changes to baseline hydrology

Location	Changes relative to conditions prior to 2015 (Before GLNG releases)	Changes relative to conditions proceeding 2015 (During desalinated water releases)
Drainage Feature (ephemeral)	Significant increase in flow frequency. Marginal increase in flow intensity.	No change
Waterhole	Changed condition from ephemeral waterhole with variable water levels, to consistent perennial water feature. Approximate increase of 1 m of standing water depth with <0.5 m variability thereafter.	No change
Waterhole Outlet	Increase in flow frequency. Marginal increase in flow intensity. Generally less than 0.14 m of water depth at the outlet was determined, attributable to the treated (desalinated) water releases, in isolation.	No change
Dawson River (Downstream of Waterhole Confluence)	Generally less than 0.06 m increase in normal conditions. Negligible increase in flood conditions.	No change
Dawson River (S4 Gauge)	Generally no more than 0.05 m increase in normal conditions. Negligible increase in flood conditions.	No change

5.3 Baseline water quality

This section characterises the baseline water quality of the proposed action area. Monitoring locations are presented in Figure 5-1, with descriptions and coordinates provided in Table 9-1.

This section summarises water quality of desalinated water within the DWB pond, the waterhole and Dawson River. Summary statistics (percentiles, minimum and maximum values) for desalinated water, waterhole and Dawson River water quality are provided in Appendix E-1 and Appendix E-2.

Analysis of water quality data is influenced by the respective analytical limit of reporting (LOR) and the number of results above the LOR. The relative confidence in a statistical summary presented in long term water quality data is dependent in on the number of actual detections above the respective LOR.

In this review of water quality and supporting Appendices (Appendix E-1, E-2 and E-3), the steps listed in Table 5-9 for the treatment of less than (<) LOR values have been completed for the purpose of calculating statistical summary of water quality data.

Table 5-9 Treatment for <LOR values in water and sediment quality analyses

% Detection	Treatment
0 – 5%	• Percentiles not calculated
5% - 50%	• Only maximum value is reported • Parameter is considered a non-exceedance of WQO
50% - 70%	• To calculate statistics, all <LOR values are substituted with LOR (ANZG, 2018) • Percentiles are considered low reliability due to high number of non-detects
>70%	• To calculate statistics, all <LOR values are substituted with LOR (ANZG, 2018) • Percentiles, where reported, are considered high reliability

Notes
- Where the number of detections is less than three in a data set irrespective of total percentage the percentiles are not calculated (e.g. 1 detection from 5 results)

5.3.1 Desalinated water quality

Desalinated water quality data from the DWB pond (monitoring location HCS04DWB1) located within HCS04 ROP, Figure 5-1) has been collected since 2015 (158 samples). Data collected between April 2015 and October 2021 was used to characterise the desalinated water quality for the proposed action, with summary statistics (percentiles, minimum and maximum values) for desalinated water presented in Appendix E-1 and Appendix E-2. A summary of key parameters in desalinated water from HCS04 DWB pond are shown in Table 5-10. With no predicted change in the treatment process at the ROP the data presented represents desalinated release water quality under the of the proposed action.

Table 5-10 Summary statistics of HCS04 DWB pond water quality

Parameter	Sub-regional WQO	ANZG (2018) Stock water	Units	HCS04 DWB Pond (HCS04DWB1)			
				20^{th} percentile	Median	80^{th} percentile	95^{th} percentile
Dissolved Oxygen - Field	7.0-9.0	-	mg/L	7.7	8.4	9.4	10.6
Electrical Conductivity @ 25°C	370	*5,970*	µS/cm	63	91	129	217
pH - Field	6.5-8.5	-	pH Unit	7.7	8.2	8.6	9.0
Suspended Solids[2]	30	-	mg/L	5	5	5	6
Ammonia as N	0.02	-	mg/L	0.03	0.07	0.14	**0.26**
Total Nitrogen as N	0.62	-	mg/L	0.1	0.2	0.3	0.4
Aluminium - dissolved	0.55	*5*	mg/L	0.01	0.01	0.02	0.03
Boron - dissolved	2.9[4]	*5*	mg/L	0.58	0.83	1.17	1.81
Zinc – dissolved[2]	0.008	-	mg/L	NC	NC	NC	NC

<table>
<tr><th rowspan="2">Parameter</th><th rowspan="2">Sub-regional WQO</th><th rowspan="2">ANZG (2018) Stock water</th><th rowspan="2">Units</th><th colspan="4">HCS04 DWB Pond (HCS04DWB1)</th></tr>
<tr><th>20th percentile</th><th>Median</th><th>80th percentile</th><th>95th percentile</th></tr>
<tr><td>Calcium - dissolved</td><td>-</td><td>1,000</td><td>mg/L</td><td>1.0</td><td>3.0</td><td>5.0</td><td>6.0</td></tr>
<tr><td>Magnesium - dissolved</td><td>-</td><td>-</td><td>mg/L</td><td>NC</td><td>NC</td><td>NC</td><td>NC</td></tr>
<tr><td>Potassium – dissolved</td><td>-</td><td>-</td><td>mg/L</td><td>NC</td><td>NC</td><td>NC</td><td>NC</td></tr>
<tr><td>Sodium - dissolved</td><td>-</td><td>-</td><td>mg/L</td><td>8.0</td><td>11.0</td><td>14.0</td><td>20.5</td></tr>
<tr><td colspan="8">Notes
State EA CL at HCS04 DWB – Schedule B4, Table 4
WQO – Upper Dawson River Sub-regional WQO (WQ1308) & ANZG (2018) DGV for Aquatic ecosystem – moderately disturbed (95% species protection level)
NC = Insufficient detections above LOR to calculate statistics
[1] – Values indicated in Bold exceed the WQO, Values indicated in Bold and Italicised exceed the Stock water guideline
[2] = low reliability statistical value due to high number of results below the limit of reporting and sample equipment source
[3] - 2.9 mg/L at ≤ 13.5ML/Day OR 2.5mg/L at ≤18.0 ML/day
[4] = Boron SSWQG (AECOM, 2019)</td></tr>
</table>

A review of REMP water quality data for the HCS04 DWB Appendix E-1 was completed and summarised in Table 5-10 against the State EA CL the sub-regional WQO and ANZG (2018) stock water limits (relevant to the drainage feature upstream of the waterhole only) in accordance with the screening process summarised in Section 3.4. The water quality screening process revealed the following:

- State EA CL
  - The median value (DO, EC, pH, SS) and 95th percentile (toxicants) for all parameters are below the State EA CL
  - However, six dissolved zinc samples were detected with concentrations above the State EA CL/sub-regional WQO (0.008 mg/L) between March 2021 and January 2022 ranging between 0.013 mg/L and 0.142 mg/L) based on Santos data collected via an auto-sampler installed in the DWB pond.
    - Review of the data by Santos indicated dissolved zinc detected in 2021 appeared abnormal to historical data dominated by concentrations below detection level (<0.005 mg/L) (Figure 5-17) triggering further assessment of potential sources during 2021.
    - The 2021 investigation consisted of sampling water through each stage of the water treatment process and identified that in the absence of detections through the treatment process the permanent monitoring and sampling equipment was a likely potential source.
    - This was confirmed through a change in sampling equipment to sampling via a bailer rather than the auto-sampler with subsequent zinc concentrations being below the LOR consistently through 2022 bar one detection in April 2022 (0.012 mg/L) and August 2022 (0.006 mg/L).
    - The auto-sampler has been taken out of service and since the change to manual dissolved zinc concentrations have been below the LoR bar one sample in April marginally above the State CL/sub-regional WQO.
    - Review of dissolved zinc concentrations in the waterhole (Figure 5-17 and Appendix E-2) have not indicated concurrent elevated concentrations or persistent detections with WLMP1, WLMP4 and WLMP5 being 5%, 4% and 10% respectively.
- Sub-regional WQO
  - the 95th percentile for ammonia (0.26 mg/L) exceeds the sub-regional WQO (0.02 mg/L)
    - Similar to zinc a review of potential ammonia sources has been carried out by Santos.

  - Review of ammonia concentrations in HCS04 ROP feed water and various locations through the water treatment process did not identify elevated levels of ammonia.
  - Anecdotal evidence indicates water birds use the DWB pond and are a viable contribution to ammonia concentrations via bird droppings/faeces.
  - Review of ammonia concentrations from WLMP5 in the waterhole against HCS04 DWB pond data (Figure 5-18) does not indicate concurrent elevated levels of ammonia.
- Stock water guidelines – applied based on stock access to desalinated water releases
  - o no parameter exceeds applicable stock water guidelines.

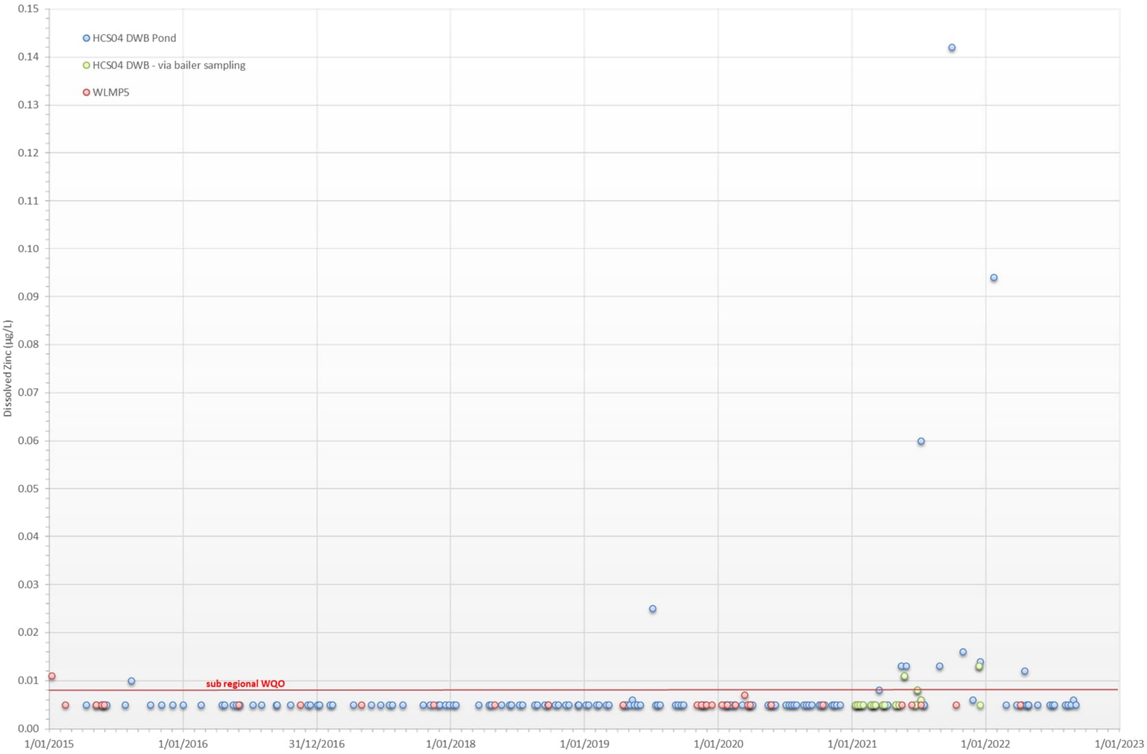


Figure 5-17 Dissolved zinc in HCS04 DWB pond and WLMP5 (2015 to 2021)

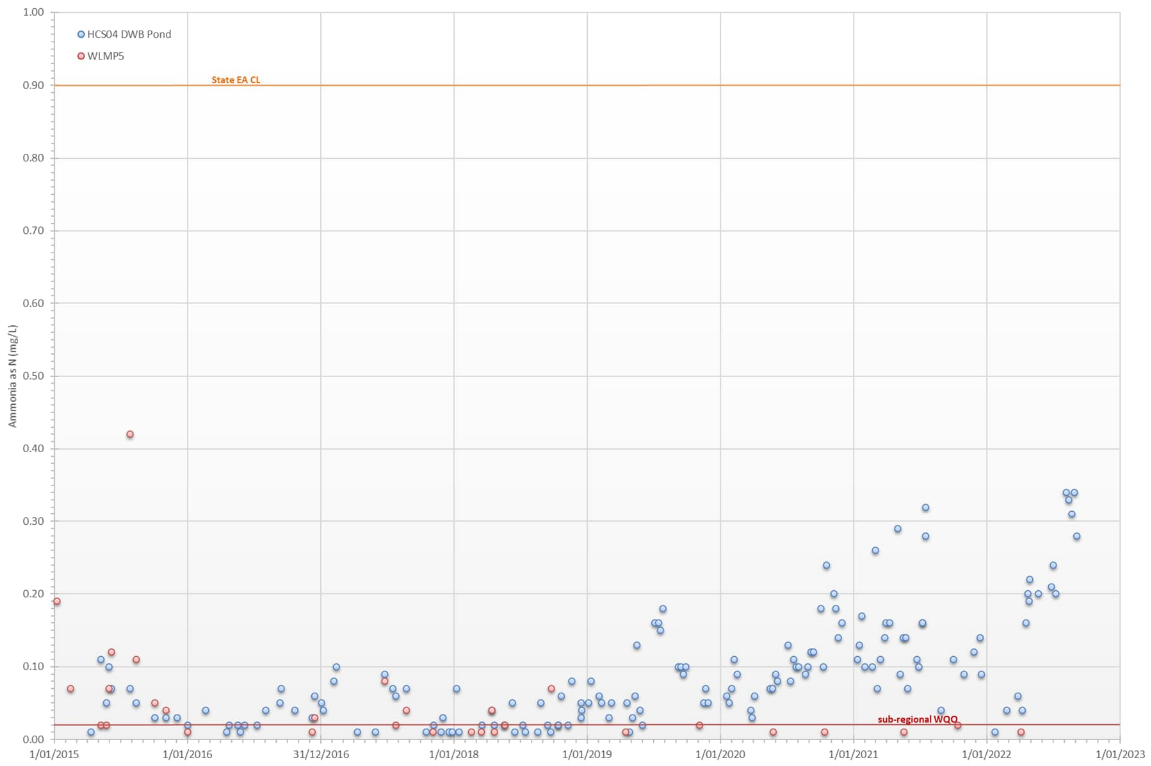


Figure 5-18 Ammonia in HCS04 DWB pond and WLMP5 (2015 to 2021)

Review of desalinated water major soluble ions is included in Appendix E-1. Of the major ions (calcium, magnesium, sodium, potassium) only calcium and sodium were consistently detected above the respective LOR. Of the major anions (chloride, sulphate) only chloride was consistently detected above the LOR and sulphate detected 14 times from 157 samples.

The relative distribution (variability) of the detected major ions and EC is presented in Figure 5-19 and summarised in Table 5-11. As stated in Section 2.2.1.3 calcium chloride dehydrate is added to the desalinated water to reach a target Ca-Cl concentration of 5–18 mg/L and a range of SAR of between 2 and 20 to maintain calcium levels for maintenance of crustacean shell growth. As such calcium increases between desalinated water and the waterhole. Sodium and chloride concentrations in desalinated water are similar to waterhole water and require no adjustment. Remaining ions are below the respective LOR in desalinated water from HCS04 DWB.

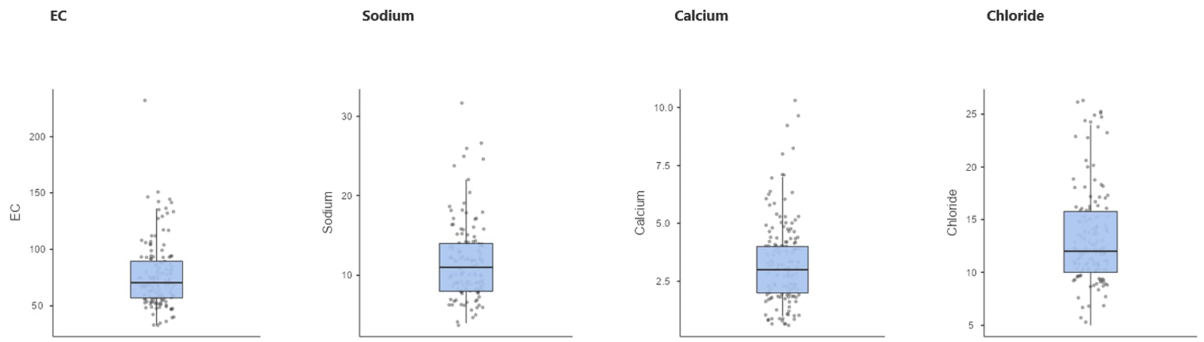


Figure 5-19 Boxplots of major ions and EC in desalinated water

Table 5-11 DWB Pond water major ions summary statistics

Parameter	Units	HCS04 DWB Pond			WLMP5		
		20th percentile	Median	80th percentile	20th percentile	Median	80th percentile
EC – Field	µS/cm	63	91	129	136	160	214
Calcium	mg/L	1.0	3.0	6.0	10.0	13.0	18.0
Chloride	mg/L	10.0	13.0	20.4	10.4	11.5	20.0
Sodium	mg/L	8.0	12.0	18.0	10.0	12.0	16.0
Sulphate as SO_4^{2-}	mg/L	2	3	5	NC	NC	NC

Notes
NC – Not calculated – less than 10 detections to allow calculation of a meaningful statistic

5.3.2 Drainage feature water quality

The drainage feature is highly ephemeral with water coming from the existing desalinated water releases and/or occasional overland flow from rain events. As such, the water quality in the drainage feature under the proposed action will be the same as current desalinated water quality summarised in Table 5-10 and Appendix E-1 and Appendix E2.

5.3.3 Waterhole water quality

Baseline water quality monitoring was conducted between 2013 and 2015 to establish site-specific water quality data for the REMP. Subsequently water quality monitoring within the waterhole has been undertaken at least twice yearly since desalinated water releases started in 2015 under the REMP. Annual REMP monitoring reports are provided in Appendix F. Summary statistics (percentiles, minimum and maximum values) for the waterhole water quality are provided in Appendix E-1 and Appendix E-2.

There are five monitoring locations within the waterhole (WLMP1, WLMP2, WLMP3, WLMP4 and WLMP5), as shown in Figure 5-1. Three waterhole locations WLMP1, WLMP4 and WLMP5 are regularly sampled under the REMP. A summary of the data for WLMP5 is presented in Table 5-12 which presents the waterhole water quality for selected parameters.

Data from these locations collected prior to 2015 is also included in this review of baseline conditions for the waterhole to inform subsequent impacts from the proposed action.

For the purpose of baseline waterhole characterisation the median (50th percentile) values for physicochemical parameters (DO, pH, EC etc) are assessed against respective WQOs (DES, 2022), and 95th percentiles for nutrients, dissolved metals and metalloids and are compared against respective WQOs (that include ANZG (2018) DGVs) and SSWQG in the case of boron as described in Section 3.4.

Review of pre-2015 data before desalinated water releases identifies nine parameters that exceeded the respective WQO as summarised in Table 5-12. Parameters exceeding respective WQO in pre 2015 data indicates pre-existing impacts not related to desalinated water releases, such as wildlife inputs or agricultural runoff for nutrients or naturally occurring in catchment soils and rock for dissolved metals.

The following four parameters of the nine pre-2015 parameters also exceeded the respective WQO after desalinated water releases started:

- dissolved aluminium
- ammonia as N
- nitrite + nitrate as N
- total nitrogen as N

Of the above four parameters ammonia, nitrite + nitrate and total nitrogen decreased in concentration within the waterhole after the start of desalinated water releases, indicating an improvement of water quality. All other parameters decreased to below the respective WQO after the start of desalinated water releases in 2015, also indicating an improvement in water quality associated with the increased water volume.

In the case of aluminium, the observed increase between pre-2015 and post-2015 is minimal (0.04 mg/L change in the upper 95th percentile). This change was statistically assessed via an initial test for normal distribution of data using the Shapiro-Wilks test that indicated the aluminium data as not normally distributed ($p < 0.001$). A non-parametric comparison was applied (paired Wilcoxon test) as a result. This indicated no statistically significant difference ($W = 0.00$, $p = 0.059$) between pre-GLNG ($n = 39$, median = 0.02 mg/L) and post-GLNG ($n = 8$, median = 0.03mg/L) aluminium levels. This comparison is graphically represented in Figure 5-20.

Reference to HCS04 DWB data in Table 5-12 indicates that only zinc and ammonia are present in desalinated water above respective receiving environment WQO. As discussed above both these parameters were investigated and found to be associated with either sampling equipment and local wildlife, as discussed in Section 5.3.1.

Both zinc and ammonia were detected at lower concentration than the baseline conditions within the waterhole. In both cases ammonia and zinc decreased in the waterhole after desalinated water releases started, indicating the desalinated water was not the primary contributing factor to zinc and ammonia concentrations in the waterhole, and were in fact lowering the concentration, as indicated in Figure 5-17 and Figure 5-18.

The 95th percentile value for dissolved boron in the waterhole (1.35 mg/L) did not exceed the SSWQG (2.9 mg/L) for 95% species protection level (see Appendix E-1) but did display an increase between pre-2015 and post-2015 data for the waterhole. Whilst the increase is noted, the 95th percentile concentration (1.23 mg/L) remained below both the State EA CL (4 mg/L) and SSWQG and is not considered to represent a significant issue for waterhole water quality. It is also noted that many agricultural fertilisers contain boron as a plant micro-nutrient, and runoff from adjacent cropping land may contribute to boron in the waterhole confounding water quality data collected under the REMP.

Table 5-12 Summary of WQ parameters above WQO in desalinated water and WLMP5

Parameter	Units	Representative WQO assessment measure	Sub-regional WQO	HCS04 DWB (HSC04DWB1) 2015 - 2021	WLMP5 2013 - 2015	WLMP5 2015 - 2022
Dissolved Oxygen - Field	mg/L	Median	7.0 – 9.0	8.2	**9.2**	7.5
Electrical Conductivity - Field	µS/cm	Median	370 (base flow) 210 (high flow)	91	**464**	160
Suspended Solids	mg/L	Median	30	5	**46**	8
Aluminium (dissolved)	mg/L	95th percentile	0.055	0.03	**0.15**	**0.19**
Copper (dissolved)	mg/L	95th percentile	0.0014	0.001	**0.003**	0.004[1]
Zinc (dissolved)	mg/L	95th percentile	0.008	**0.013**[1]	**0.012**	0.011[2]
Ammonia as N	mg/L	95th percentile	0.02	**0.26**	**0.26**	**0.16**
Nitrite + Nitrate as N	mg/L	95th percentile	0.06	0.02	**0.11**	**0.08**
Total Nitrogen as N	mg/L	95th percentile	0.62	0.4	**4.04**	**1.46**

Notes
1 – Low reliability value due to high number of <LOR values and result from cross contamination from sampling equipment (Section 5.3.1)
2 - Maximum value reported due to <50% detection rate >LOR. Value likely to overstate 'true' site levels, result is considered a non-exceedance (see Table 5-9).
" – " = No EA limit for this parameter
Bold value = Exceeds EA limit or WQO

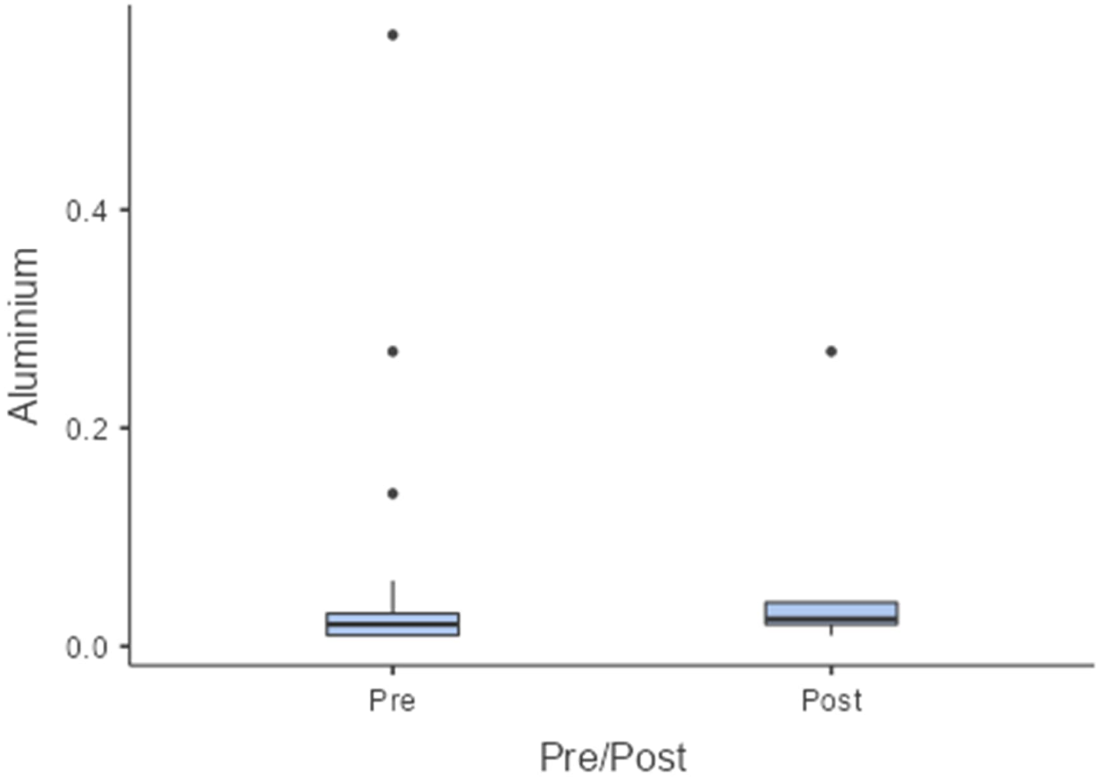


Figure 5-20 Box-plot comparing waterhole (WLMP5) dissolved aluminium levels (mg/L) in the pre- and post-desalinated water release conditions

REMP monitoring results are consistent with the expected outcomes reported in the modelling performed in the Impact Resilience Assessment (Santos 2012). The water quality assessment for the waterhole system utilised the US EPA Water Quality Analysis Simulation Program (WASP 7.3) to interpret and predict water quality responses in the waterhole to the release of desalinated water. The WASP7.3 modelling did not predict a significant impact to water quality from the maximum desalinated release rate.

In summary, overall waterhole water quality is improved from pre-2015 conditions before the start desalinated water releases. Current waterhole water quality following the start of desalinated water releases in 2015 displays decreased (nutrients) or similar (dissolved aluminium) concentrations in monitored parameters including those that were above the respective WQO both before and after desalinated water releases started in 2015 (aluminium, ammonia, nitrate+nitrite and total nitrogen) which appear to be associated with ambient conditions of the catchment.

5.3.4 Waterhole ecological indicators

5.3.4.1 Macrobenthos

The GLNG Project desalinated release REMP monitoring includes assessment of ecological indicators outlined in Table 3-7 in Section 3.4.2.

Baseline ecological data from 2013 to 2015 were used to develop local biological objective (LBO) for reference in REMP monitoring. Waterhole conditions during the 2013 to 2015 baseline surveys were stated (frc environmental, 2021) to be dry to very shallow water depths.

Data from both baseline monitoring prior to GLNG desalinated water releases and post GLNG desalinated water release REMP ecological monitoring data is summarised in Table 5-13 and indicates the following:

- Abundance displays a large variability over the 2013 to 2022 survey period in all three waterhole locations with higher abundance recorded in 2014, 2015, 2018 and 2022 (Figure 5-21). Overall trends appear stable based on a linear trend.
- Taxonomic richness exceeds the upper LBO percentiles from November 2017 to 2019 and 2022 suggesting a greater diversity of species present in the waterhole during these years. Long term trends appear to slightly increase based on a linear trend.
- PET[25] richness similarly displays a high level of variability (Figure 5-21) and exceeds the upper LBO from 2016 – 2019 and April 2022.
- SIGNAL-2 exceed the upper LBO in 2013, 2017, 2018, 2019, 2020 (bar WLMP1), 2021 before decreasing slightly in 2022. Similar to taxonomic richness, long term trends of SIGNAL-2 display a slightly increasing trend (Figure 5-21).
- Macrocrustacean exoskeleton condition appears to be good across all surveys except the 2016 survey where two Cherax destructor (Common yabby/Queensland crayfish) captured during the post-wet season survey were noted to be soft to fingertip pressure. Examples of Cherax destructor captured during the following pre-wet season survey were noted to have exoskeletons in a robust and good condition.

Conclusions from annual REMP reporting (Appendix F) state that taxonomic richness and Signal-2 scores was higher than the pre-GLNG baseline condition reflecting a positive change associated with improved habitat quality within the waterhole. The annual REMP monitoring consistently states that the GLNG Project desalinated water releases has not impacted the aquatic environmental values and has overall enhanced the waterhole habitat for aquatic species.

5.3.4.2 Native and exotic fish

REMP fish survey data is summarised in Table 5-14 and indicates the following:

- the number of species remains above the LBO in all locations within the waterhole, and
- observed to expected ratio is above the LBO remaining within a range of 1 to 2.5 range and does not indicate an overall decline in fish species.
- non-native fish were observed in WLMP1 in 2015 and in WLMP4 and WLMP5 in 2017. No non-native species have been recorded in the waterhole since 2017.

The number of species and observed to expected ratio increases from initial rounds in 2015 collected before desalinated water releases started and typically returning an observed to expected ratio of 1 and increasing to higher ratios from 2017 onwards. This trend indicates that desalinated water releases have increased fish diversity in the waterhole.

For non-native fish, reference to the Queensland Government WetlandInfo table for identified ray-finned fish in the Dawson River drainage sub-basin identifies 39 species of fish to be present including the non-native goldfish (*Carassius auratus*) and mosquitofish (*Gambusia holbrooki*) and European Carp (*Cyprinus carpio*).

Queensland Government data indicates the non-native species observed in the waterhole in 2015 and 2017 are already present in the Upper Dawson River sub-catchment.

[25] Macroinvertebrates belonging to the orders Plecoptera, Ephemeroptera, and Trichoptera (PET) order; considered to be sensitive to changes in their environment (DES, 2018)

Table 5-13 Summary of waterhole REMP macrobenthic data 2013 – 2021 per location

Waterhole WLMP1																					
Ecological Index	**Local Biological Objective**	**Aug-13**	**Nov-13**	**Jan-14**	**Apr-14**	**Jul-14**	**Oct-14**	**May-15**	**Nov-15**	**May-17**	**Nov-17**	**May-18**	**Sep-18**	**Apr-19**	**Nov-19**	**May-20**	**Oct-20**	**May-21**	**Oct-21**	**Apr-22**	**Sep-22**
Macroinvertebrates																					
Abundance	92.3-252.8	136.5	187.5	106	212	314	**324.5**	211	142	**46**	**63**	474	**275**	115	211	**30**	**83**	**71**	**62**	147	**260**
Taxonomic Richness	5.67-10.8	6.5	8	**5**	**11**	9	8.5	10	**18**	9	**12**	**13**	**16**	**15**	**15**	8	8	6	7	**14**	**13**
PET Richness	0.0-1.2	0	0	0	1	1	0	1	1	1	**2**	**2**	**3**	1	1	0	0	0	0	**2**	0
SIGNAL-2 Score	2.65-3.2	3.1	2.7	3.1	2.9	2.8	2.9	2.9	2.9	**3.3**	**3.3**	**3.6**	3.2	3.2	2.8	2.9	2.9	**3.3**	**3.4**	3.2	2.9
Macrocrustacean exoskeleton																					
No. Species	1	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	1	1	1	2	2	1	3	3	2	2	3	2	1	#N/A
Condition	g	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	g	g	g	g	g	g	g	g	g	g	g	g	g	#N/A
Waterhole WLMP4																					
Ecological Index	**Local Biological Objective**	**Aug-13**	**Nov-13**	**Jan-14**	**Apr-14**	**Jul-14**	**Oct-14**	**May-15**	**Nov-15**	**May-17**	**Nov-17**	**May-18**	**Sep-18**	**Apr-19**	**Nov-19**	**May-20**	**Oct-20**	**May-21**	**Oct-21**	**Apr-22**	**Sep-22**
Macroinvertebrates																					
Abundance	92.3-252.8	107.5	206.5	123	**88**	#N/A	#N/A	**313**	194	132	177	**351**	**364**	100	148	67	132	150	217	133	159
Taxonomic Richness	5.67-10.8	6.5	6	6	8	#N/A	#N/A	**11**	10	**12**	**21**	**13**	**13**	**20**	10	**13**	**16**	**16**	**18**	11	11
PET Richness	0.0-1.2	1	0	0	0	#N/A	#N/A	**2**	0	**2**	**3**	**2**	**3**	**2**	1	**2**	**3**	**2**	**2**	0	1
SIGNAL-2 Score	2.65-3.2	3.2	3	3.1	**2.6**	#N/A	#N/A	3.1	3	**3.5**	3.2	**3.5**	**3.6**	3.1	**3.4**	**3.5**	**3.5**	**3.7**	3.1	**3.3**	**3.5**
Macrocrustacean exoskeleton																					
No. Species	1	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	1	1	1	2	2	1	3	3	2	2	3	2	1	#N/A
Condition	g	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	g	g	g	g	g	g	g	g	g	g	g	g	g	#N/A
Waterhole WLMP5																					
Ecological Index	**Local Biological Objective**	**Aug-13**	**Nov-13**	**Jan-14**	**Apr-14**	**Jul-14**	**Oct-14**	**May-15**	**Nov-15**	**May-17**	**Nov-17**	**May-18**	**Sep-18**	**Apr-19**	**Nov-19**	**May-20**	**Oct-20**	**May-21**	**Oct-21**	**Apr-22**	**Sep-22**
Macroinvertebrates																					
Abundance	92.3-252.8	121.5	213	93	315	198	192	246	**37**	136	189	**325**	252	96	**289**	**67**	100	**54**	**61**	**86**	**255**
Taxonomic Richness	5.67-10.8	**5**	6	**5**	8	9	8	**12**	**11**	10	**14**	**14**	**12**	6	**12**	**13**	10	**5**	9	**11**	**15**
PET Richness	0.0-1.2	0	0	0	1	0	0	**2**	1	**2**	**4**	**3**	**2**	0	**3**	**2**	1	0	0	1	1
SIGNAL-2 Score	2.65-3.2	**3.3**	3.1	3.2	2.7	2.8	2.9	2.8	2.9	**3.4**	**3.5**	**3.8**	**3.4**	**3.3**	**3.5**	3.2	3.2	**3.4**	**3.3**	**3.4**	3.1
Macrocrustacean exoskeleton																					
No. Species	1	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	1	1	1	2	2	1	3	3	2	2	3	2	1	#N/A
Condition	g	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	g	g	g	g	g	g	g	g	g	g	g	g	g	#N/A

Notes
Local Biological Objective is the 20th percentile and 80th percentile from frc environmental (2016) baseline surveys collected over 7 surveys between 2013 and 2015
2021 – post-wet season REMP data only
Where a pre-wet and post wet season survey completed results are presented as pre/post
g = good exoskeleton condition
s = soft exoskeleton condition
2015 REMP report displays combined data from 2015 post-wet (May) and pre-wet (November) data
#N/A - non-sampled (used to maintain representation of data in graphs)
DRR1 (Upstream) previously named RS1 (2013-2014)
Results in bold are outside the 20th to 80th percentile range

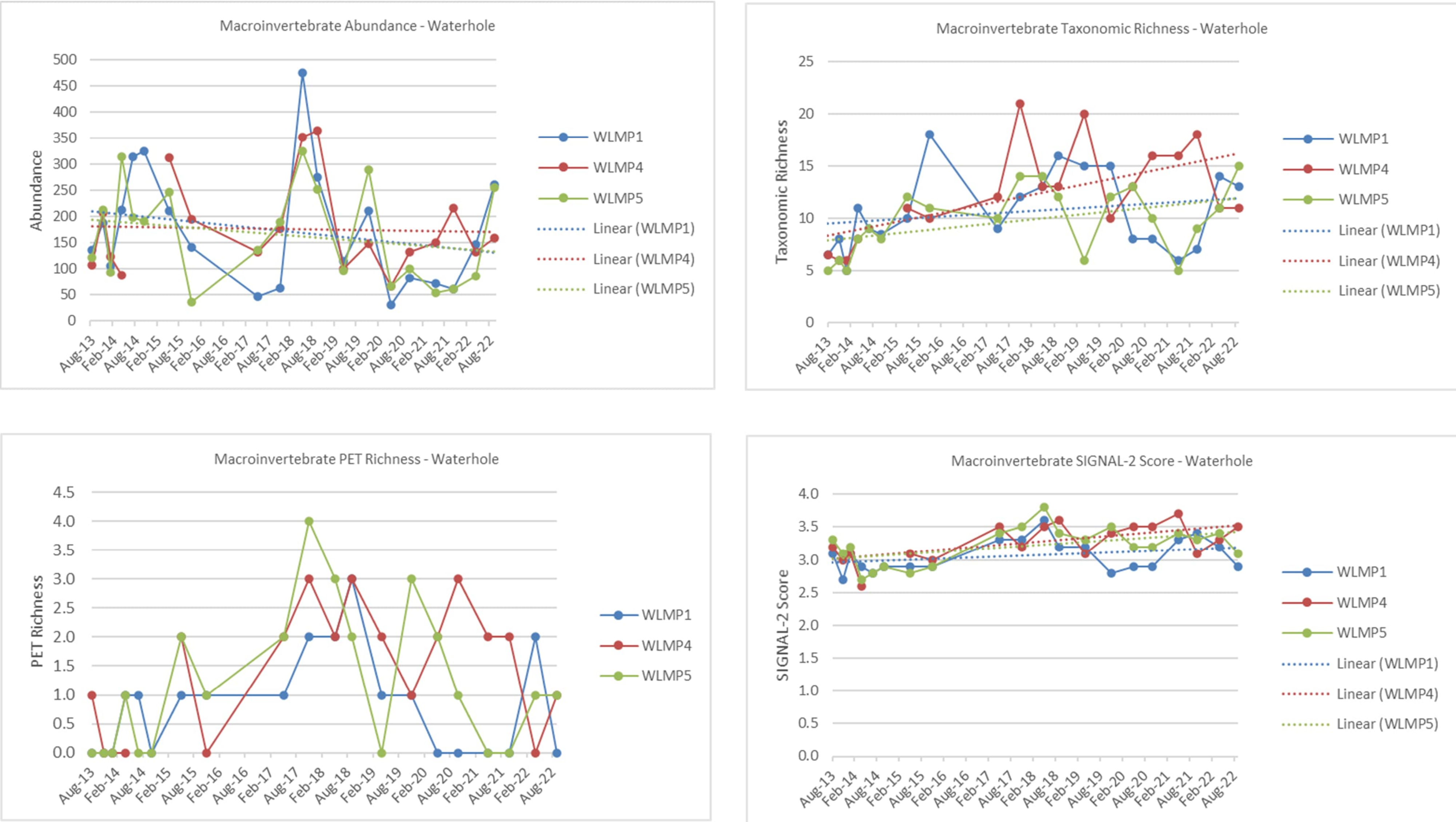


Figure 5-21 Summary of waterhole REMP macrobenthic trends 2013 – 2021

Table 5-14 Summary of REMP waterhole fish survey data 2015 to 2021

Waterhole WLMP1													
Ecological Index	**LBO**	**May-15**	**Nov-15**	**May-17**	**Nov-17**	**May-18**	**Sep-18**	**Apr-19**	**Nov-19**	**May-20**	**Oct-20**	**May-21**	**Oct-21**
Fish													
No. Species	≥4	4	4	4	6.00	4.00	6.00	5.00	7.00	7.00	6.00	8.00	6.00
Observed:Expected	≥1	1	1	1.5	2.00	1.50	1.75	2.00	1.75	2.00	1.75	2.50	1.75
Non-native species	0	0	1	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Waterhole WLMP4													
Ecological Index	**LBO**	**May-15**	**Nov-15**	**May-17**	**Nov-17**	**May-18**	**Sep-18**	**Apr-19**	**Nov-19**	**May-20**	**Oct-20**	**May-21**	**Oct-21**
Fish													
No. Species	≥4	**3**	0	6	7.00	5.00	5.00	4.00	4.00	5.00	5.00	5.00	5.00
Observed:Expected	≥1	1	1	1.5	2.00	1.50	1.75	2.00	1.75	2.00	1.75	2.50	1.75
Non-native species	0	0	0	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Waterhole WLMP5													
Ecological Index	**LBO**	**May-15**	**Nov-15**	**May-17**	**Nov-17**	**May-18**	**Sep-18**	**Apr-19**	**Nov-19**	**May-20**	**Oct-20**	**May-21**	**Oct-21**
Fish													
No. Species	≥4	**3**	4	6	6.00	4.00	7.00	7.00	5.00	5.00	6.00	9.00	5.00
Observed:Expected	1	1	1	1.5	2.00	1.50	1.75	2.00	1.75	2.00	1.75	2.50	1.75
Non-native species	0	0	0	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes
Observed:Expected WQO is derived from the Upper Dawson River sub-regional WQO and REMP
#N/A - non-sampled (used to maintain representation of data in graphs)
No. of species LBO obtained from REMP

5.3.5 Dawson River baseline water quality

5.3.5.1 Dawson River water quality

An assessment of REMP data from monitoring locations DRR1 (upstream of the waterhole-Dawson River confluence) and DRMP1 and S4 (downstream of the waterhole-Dawson River confluence) (Appendix E-2) collected between 2013 (biological) and 2015 (water and sediment) to 2022 was undertaken to demonstrate current baseline Dawson River water quality (DRR1) and desalinated-water influenced WQ (DRMP1 and S4) for the proposed action.

Review of data for S4 (Appendix E-2 and Table 5-15)as the compliance point for the State EA (Schedule B Table 5) indicates none of the parameters are above the respective State EA CL bar total nitrogen, common component of both artificial and natural agricultural fertiliser.

The median for EC and 95th percentile for the remaining parameters exceeded the respective sub-regional WQOs in the downstream locations DRMP1 and S4 as indicated in Table 5-15:

- electrical conductivity (EC) (conservatively assuming the lower high flow WQO)
- dissolved aluminium
- ammonia as N
- nitrite + nitrate as N
- total nitrogen as N.

The following is noted, however, indicating that these exceedances are predominately driven by upstream/regional effects rather than GLNG releases:

- each of these parameters shows a corresponding exceedance at the upstream reference location DRR1 indicating they are the result of regional conditions (e.g. agriculture or geological) upstream of the desalinated water discharge to Dawson River
- in the case of aluminium, ammonia, and nitrogen, water quality actually improves downstream of the confluence, suggesting a water quality improvement for these parameters associated with desalinated water releases
- in the case of EC:
  - the elevation at DRMP1 is marginal (2 µS/cm difference in the median value of DRR1)
  - EC levels detected above the WQO at DRMP1 return to upstream levels at S4
  - applying the Reference Site Method that assesses whether the median DRMP1 value falls between the 20th and 80th percentile value for the upstream site DRR1 (ANZG, 2018; DEHP, 2013) indicates no significant departure from the reference condition (see Appendix E-2) and no significant change

In the case of nitrite + nitrate, the observed increase is considered marginal, and unlikely or minimally attributable to desalinated water releases based on the following:

- although levels increase between DRR1 and DRMP1, they attenuate to below-upstream levels by S4
- applying the reference site method (comparing DRMP1 median to DRR1 80th percentile) suggests no significant departure from reference conditions (DRMP1 median = 0.01 mg/L, DRR1 80th percentile = 0.10 mg/L)
- the low levels observed in desalinated water (95th percentile = 0.02 mg/L) suggest that it is unlikely that this source is driving the increase observed at DRMP1.

Reference to HCS04 ROP data for the above parameters indicates that, with the exception of ammonia, the respective parameter concentrations are below the WQO and upstream reference concentration indicating that desalinated water entering the Dawson River between DRR1 and DRMP1 is not impacting the receiving water via the discharge.

For ammonia, whilst the HCS04 ROP data indicates a concentration greater than the DRR1 upstream reference point, the downstream 95th percentile concentration in DRMP1 is below the upstream and the S4 compliance point 95th percentile concentration is the same as the upstream reference concentration indicating no significant increase in ammonia associated with desalinated water release.

Table 5-15 Summary of parameters exceeding State EA limits or WQO in Dawson River or desalinated water

Parameter	Units	Representative measure	State EA CL S4	Sub-regional WQO	HCS04 DWB Pond 2015 - 2021	DRR1 2015-2022 (upstream)	DRMP1 2015-2022 (downstream)	S4 2015-2022 (downstream)
Electrical Conductivity - Field	µS/cm	Median	370 (75th %ile)	210 (high flow)	91	**273**[1]	**275**[1]	**273**[1]
Aluminium (dissolved)	mg/L	95th percentile	0.2	0.055	0.03	**0.26**	**0.13**	NA
Ammonia as N	mg/L	95th percentile	-	0.02	**0.26**	**0.10**	**0.08**	**0.10**
Nitrite + Nitrate as N	mg/L	95th percentile	-	0.06	0.02	**0.45**	**0.74**	**0.38**
Total Nitrogen as N	mg/L	95th percentile	0.62	0.62	0.4	**2.0**	**1.7**	**1.9**

Notes

1 – Conservatively listed as an exceedance assuming high-flow sampling

2 – Limited confidence in percentile value as number of detects >LOR is less than 30%

" – " = No State EA limit for this parameter

EC – median value of 2015 – 2022 REMP data referenced against the high flow sub-regional WQO for conservatism

Other parameters – 95th percentile of 2015 – 2022 REMP data

Bold value = Exceeds State EA limit or WQO

NA = Not assessed – insufficient detections above the LOR

Data collected from DRR1 (upstream of the waterhole confluence) under the GLNG Project REMP did not detect dissolved boron above the limit of reporting (<0.05 mg/L). Detection of boron was recorded downstream of the waterhole discharge location (DRMP1 median = 0.05 mg/L). Boron load to the Dawson River however appears to be via total boron rather than dissolved boron, based on the lower number of detections for dissolved boron over total boron (Appendix E-2).

The lower median concentration of boron in DRMP1 compared to WLMP5 (0.23 mg/L) indicates attenuation occurs at the discharge location (as predicted in revised modelling). Furthermore, dissolved boron levels at DRMP1 (95^{th} percentile = 0.22 mg/L) and S4 (maximum = 0.24 mg/L) remain below the site-specific guideline value of 2.9 mg/L, and the ANZG (2018) 99% species protection level of 0.34 mg/L: indicating minimal ecological risk from boron.

Overall, the assessment indicates that waterhole discharges to the Dawson River do not appear to impact downstream water quality with attenuation of boron occurring to near reference background values within the proposed action area.

5.3.5.2 Ionic balance of receiving environment

It is noted that the desalinated water is lower in some salts – such as calcium, magnesium, potassium and sodium, relative to the receiving environment (Appendix E-2). IESC (2018) advises requires proponents provide:

- a description of the current condition and quality of water resources and information on condition trends
- adequate water and salt balances, and
- identification of potential thresholds for each water resource and its likely response to change and capacity to withstand adverse impacts (e.g. altered water quality, drawdown).

To mitigate issues related to calcium deficiency, desalinated water is treated with calcium prior to release, and the State EA incorporates a minimum calcium level of 1 mg/L for desalinated water in the HCS04 DWB pond (Appendix E-2). The following presents analyses to support that desalinated water releases are not creating a significant disturbance from upstream conditions in the receiving environment in terms of ionic balance.

Applying the reference site approach from ANZG (2018) and DEHP (2013), a parameter is considered within the variability of reference (i.e. baseline) conditions if its median value is within the falls between the 20^{th} and 80^{th} percentile of upstream values. Table 5-16 presents a comparison between upstream (DRR1) and downstream (DRMP1 and S4) median values for selected ions.

Table 5-16 Ionic balance comparisons for upstream and downstream sites

		DRR1 (upstream)		DRMP1 (downstream)	S4 (downstream)
Parameter	Units	20^{th} percentile	80^{th} percentile	Median	Median
Electrical Conductivity – Field	µS/cm	241	290	275	273
Calcium	mg/L	14	18	16	17
Chloride	mg/L	18	24	22	23
Sodium	mg/L	23	31	29	31
Fluoride	mg/L	0.1	0.1	0.1	0.1
Sulphate as SO_4^{2-}	mg/L	1	1	1	1

Table 5-16 supports the conclusion that desalinated water releases are not representing a significant change from baseline (upstream) conditions in terms of ionic balance. Neither a significant elevation nor reduction in salt levels is observable in the downstream receiving environment. This is further supported by data visualisations and statistical analyses, representing the distribution of the respective locations' datasets.

Figure 5-22 resents boxplots and frequency distributions for EC and sodium levels at the respective sites. These visualisations indicate statically similar EC and sodium levels and show a comparable variability and data distribution for these salts at each location.

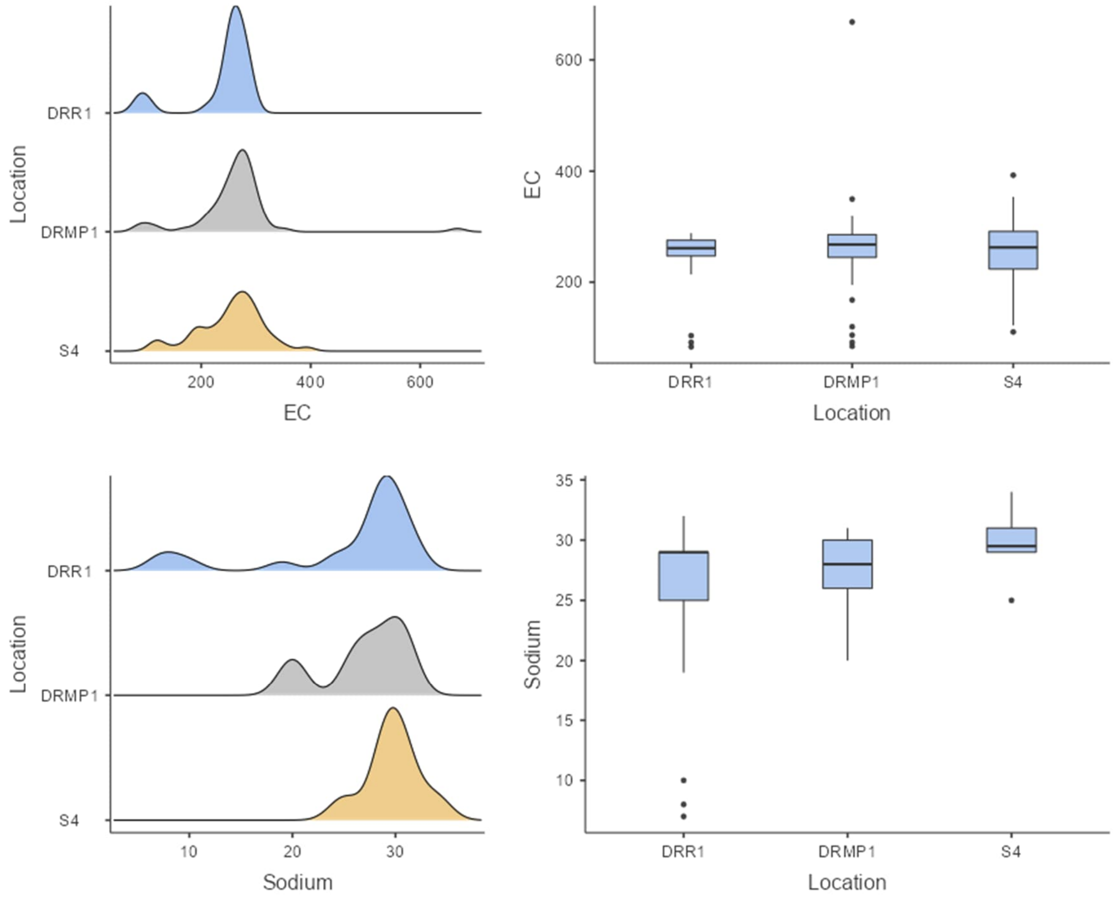


Figure 5-22 Frequency distribution and boxplots for upstream and downstream EC and sodium levels

Statistical analyses found no significant difference at the p <0.05 level between locations for EC and sodium. Dwass-Steel-Critchlow-Fligner pairwise comparisons results are presented in Table 5-17. In all cases, p >0.05 indicating no statistically significant differences between locations.

Table 5-17 Statistical comparisons of upstream and downstream Dawson River salt levels

Pairwise comparisons – EC				Pairwise comparisons – Sodium			
Monitoring location		W	p	Monitoring location		W	p
DRR1	DRMP1	1.795	0.413	DRR1	DRMP1	0.0466	0.999
DRR1	S4	1.129	0.704	DRR1	S4	2.3672	0.215
DRMP1	S4	-0.190	0.990	DRMP1	S4	1.5722	0.507

5.3.5.3 Dawson River ecological quality indicators

Macrobenthos

Ecological data from REMP monitoring for the Dawson River sampling locations DRR1 (upstream), DRMP1 (downstream) and S4 (State EA monitoring point) is summarised in Table 5-18 and indicates the following:

- Abundance displays a large degree of variability between 2013 and 2022 being above the upper LBO in 2018, 2020, 2021 and decreasing in 2022 (possibly associated with the wetter than average year). Long term linear trends display a slight increase in DRR1 and S4 with no significant trend in DRMP1 (Figure 5-23)

- Taxanomic richness generally similarly displays variability, being above the upper LBO in 2017, 2018, and 2021 before decreasing over 2022. Long term linear trends are level and do not display either an increasing or decreasing trend (Figure 5-23)
- PET richness displays a variable range over the 2013 to 2022, with a similar decrease through 2022, over the wetter than average year.
- SIGNAL-2 scores are within or exceed the upper LBO bar 2015 and 2016 which were slightly below the lower LBO. Long term linear trends do not display a significant increasing or decreasing trend over the 2013 to 2022 period.
- Microcrustacean exoskeleton condition appears to be good across all REMP surveys

The REMP ecological indicators do not appear to indicate a significant change in the Dawson River between 2013 and 2022. Similar to the waterhole, the annual REMP monitoring consistently states that the desalinated water releases has not impacted the aquatic environmental values. Annual REMP monitoring reports can be referenced in Appendix F.

Native and exotic fish

REMP fish survey data is summarised in Table 5-19 and indicates the following:

- the number of species is variable both spatially and over the time period from 2015 to 2022 with no consistent trend between upstream and downstream locations
- observed to expected ratio exceeds the LBO ranging from 1.2 to 2.2 displaying no variance between upstream and downstream locations.
- no non-native fish have been recorded in any of the Dawson River REMP locations between 2015 and 2022.

Monitoring data indicates no apparent impact of fish associated with desalinated water releases entering the Dawson River.

Table 5-18 Summary of Dawson River REMP macrobenthos data 2013 – 2021

Ecological Index	Local Biological Objective	Aug-13	Nov-13	Jan-14	Apr-14	Jul-14	Oct-14	May-15	Nov-15	May-17	Nov-17	May-18	Sep-18	Apr-19	Nov-19	May-20	Oct-20	May-21	Oct-21	Apr-22	Sep-22
DRR1 (Upstream)																					
Macroinvertebrates																					
Abundance	39.9-152.0	**172**	**153**	106	**34**	**38**	68	#N/A	**157**	115	181	**187**	**224**	**54**	**177**	#N/A	**222**	**274**	**214**	76	**21.0**
Taxonomic Richness	9.93-16.9	11	**21**	**19**	10	12	14	#N/A	12	13	**18**	**19**	16	13	**22**	#N/A	**19**	16	15	11	**9.0**
PET Richness	1.47-4.0	1.5	4	3	**1**	2	3	#N/A	2	2	5	4	3	**1**	4	#N/A	**5**	4	4	2	**1**
SIGNAL-2 Score	3.46-4.00	3.7	3.9	3.6	3.5	**3.2**	3.6	#N/A	**3.1**	3.5	4	3.9	3.9	3.5	3.8	#N/A	3.9	4	**4.2**	**3.4**	**3.4**
Macrocrustacean exoskeleton																					
No. Species	2	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	2	2	2	1	2	3	2	2	1	2	1	#N/A
Condition	g	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	g	g	g	g	g	g	g	g	g	g	g	#N/A
DRMP1 (Downstream)																					
Macroinvertebrates																					
Abundance	39.9-152.0	#N/A	#N/A	#N/A	57	**156**	98	49	79	**34**	85	**158**	**186**	57	199	#N/A	148	142	93	71	**25**
Taxonomic Richness	9.93-16.9	#N/A	#N/A	#N/A	13	14	16	11	12	**9**	11	16	16	**9**	**18**	#N/A	15	13	15	12	**8**
PET Richness	1.47-4.0	#N/A	#N/A	#N/A	2	4	3	2	**1**	2	2	**5**	2	**1**	4	#N/A	3	4	3	**1**	**1**
SIGNAL-2 Score	3.46-4.00	#N/A	#N/A	#N/A	3.7	**4.1**	4	4	**3.3**	3.7	3.8	4	3.9	3.6	**4.1**	#N/A	3.7	**4.3**	3.9	3.6	3.8
Macrocrustacean exoskeleton																					
No. Species	2	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	2	2	2	1	2	3	2	2	1	2	1	#N/A
Condition	g	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	g	g	g	g	g	g	g	g	g	g	g	#N/A
S4 (Downstream)																					
Macroinvertebrates																					
Abundance	39.9-152.0	#N/A	#N/A	#N/A	**33**	151	140	43	**19**	51	119	**235**	**254**	53	**323**	#N/A	**211**	77	**168**	102	**12**
Taxonomic Richness	9.93-16.9	#N/A	#N/A	#N/A	10	16	11	12	**8**	11	14	**19**	13	**8**	24	#N/A	15	16	14	15	**8**
PET Richness	1.47-4.0	#N/A	#N/A	#N/A	3	4	3	**1**	**0**	3	4	5	3	**1**	**5**	#N/A	4	4	3	4	**1**
SIGNAL-2 Score	3.46-4.00	#N/A	#N/A	#N/A	3.9	3.9	**3.4**	3.6	**2.6**	3.9	3.9	4	3.8	3.7	4	#N/A	3.9	4	4	3.9	**3.4**
Macrocrustacean exoskeleton																					
No. Species	2	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	2	2	2	1	2	3	2	2	1	2	1	#N/A
Condition	g	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	g	g	g	g	g	g	g	g	g	g	g	#N/A

Notes
Local Biological Objective is the 20th percentile and 80th percentile from frc environmental (2016) baseline surveys collected over 7 surveys between 2013 and 2015
2021 – post-wet season REMP data only
Where a pre-wet and post wet season survey completed results are presented as pre/post
g = good exoskeleton condition
s = soft exoskeleton condition
2015 REMP report displays combined data from 2015 post-wet (May) and pre-wet (November) data
#N/A - non-sampled (used to maintain representation of data in graphs)
DRR1 (Upstream) accidentally named RS1 (2013-2014) in provided data
Results in bold are outside the 20th to 80th percentile range

Figure 5-23 **Summary of Dawson River REMP macrobenthic trends 2013 – 2021**

Table 5-19 Summary of REMP Dawson River fish survey data 2015 to 2021

DRR1 (Upstream)

Ecological Index	LBO	May-15	Nov-15	May-17	Nov-17	May-18	Sep-18	Apr-19	Nov-19	May-20	Oct-20	May-21	Oct-21
Fish													
No. Species	≥5	8	#N/A	8	9	6	6	6	7	**3**	5	**3**	6
Observed:Expected	1[a]	1.6	#N/A	2	2.2	2	1.2	1.5	1.8	1.2	2.2	1.4	1.2
Non-native species	0	0	#N/A	0	0	0	0	0	0	0	0	0	0

DRMP1 (Downstream)

Ecological Index	LBO	May-15	Nov-15	May-17	Nov-17	May-18	Sep-18	Apr-19	Nov-19	May-20	Oct-20	May-21	Oct-21
Fish													
No. Species	≥5	**4**	#N/A	7	5	5	**4**	**2**	**4**	**3**	11	6	5
Observed:Expected	≥1[a]	1.6	#N/A	2	2.2	2	1.2	1.5	1.8	1.2	2.2	1.4	1.2
Non-native species	0	0	#N/A	0	0	0	0	0	0	0	0	0	0

S4 (Downstream)

Ecological Index	LBO	May-15	Nov-15	May-17	Nov-17	May-18	Sep-18	Apr-19	Nov-19	May-20	Oct-20	May-21	Oct-21
Fish													
No. Species	≥5	**2**	#N/A	6	10	9	6	**3**	6	**3**	**3**	**4**	**4**
Observed:Expected	≥1[a]	1.6	#N/A	2	2.2	2	1.2	1.5	1.8	1.2	2.2	1.4	1.2
Non-native species	0	0	#N/A	0	0	0	0	0	0	0	0	0	0

Notes
a - Observed:Expected local biological objective is that for the Dawson River….
#N/A - non-sampled (used to maintain representation of data in graphs)
No. of species LBO obtained from Local Guidelines for Fish in REMP reports
May 2015 values obtained from 2015 REMP report where only one set of data was available (no separate post-wet and pre-wet sections)

5.4 Sediment quality

Sediment quality monitoring within the waterhole and Dawson River has been undertaken since desalinated water releases started in July 2015 as per the REMP. Annual REMP monitoring reports are provided in Appendix F with summary statistics (number of data, number of samples >LoR, % detection, percentiles and maximum values) for waterhole and Dawson River sediment quality data provided in Appendix E-3**.**

Screening of sediment quality utilises the 95^{th} percentile (or median for EC) of REMP data collected between 2015 and 2022 compared against ANZG (2018) DGVs or LT guidelines (Appendix E-3 and Table 5-20). Data that was <LOR were statistically accounted for as described in Table 5-9.

Table 5-20 95^{th} percentile sediment quality for waterhole and Dawson River

Sediment Quality Parameter	ANZG (2018) DGV / LT[4]	Units	LOR	Waterhole[2]	Dawson River[2]		
				WLMP5 2015-2022	DRR1 2015-2022 (upstream)	DRMP1 2015-2022 (downstream)	S4 2015-2022 (downstream)
Physicochemical Parameters							
Median Electrical Conductivity @ 25C		µS/cm	1	28	30	19	17
Metals and Metalloids							
Aluminium	13,933 / 5,191[4]	mg/kg	50	**16,280**	**10,600**	4,122	4,800
Arsenic	20[3]	mg/kg	5	<5[1]	5[1]	<5[1]	<5[1]
Boron (Total)	18.8 / 17.9[4]	mg/kg	50	<50[1]	<50[1]	<50[1]	<50[1]
Boron (Rayment et al)	18.8 / 17.9[5]	mg/kg	0.2	9	0.4	0.2[1]	<u>2.6</u>[1]
Cadmium	1.5[3]	mg/kg	1	<1[1]	<1[1]	<1[1]	<1[1]
Chromium	80[3]	mg/kg	2	13	9	4[1]	4[1]
Copper	65[3]	mg/kg	5	18	12[5]	7[1]	7[1]
Iron	17,867 / 9,353[4]	mg/kg	50	**18,960**	**16,600**	7,382	**9,547**
Lead	50[3]	mg/kg	5	17	14[5]	8[1]	10[1]
Manganese	648 / 230.5[4]	mg/kg	5	**549**	**544**	**328**	**308**
Mercury	0.15[3]	mg/kg	0.1	<0.1[1]	<0.1[1]	<0.1[1]	<0.1[1]
Nickel	21[3]	mg/kg	2	13	10	4	5[1]
Selenium	1 / 1.5[4]	mg/kg	5	<5[1]	<5[1]	<5[1]	<5[1]
Zinc	200[3]	mg/kg	5	68	44	22[5]	23[5]
Nutrients							
Ammonia as N		mg/kg	20	144	58[5]	<20[1]	<20[1]
Nitrate as N (Sol.)	No DGV or LT	mg/kg	0.1	0.4[5]	1.2[1]	0.1[1]	0.1[1]
Total Kjeldahl Nitrogen as N (TKN)	No DGV or LT	mg/kg	20	5,810	1,380	392	<u>1,600</u>

Notes
1 – Maximum value reported due to <50% detection rate. This value may overstate the 'true' maximum due to low reliability, and the result is considered a non-exceedance (see **Table 5-9**)
2 – Bold – exceeds WQO or LT, underlined – downstream Dawson River value higher than baseline (DRR1) value
3 – Default guideline value from ANZG (2018)
4 – LT = waterhole / Dawson River

Sediment Quality Parameter	ANZG (2018) DGV / LT[4]	Units	LOR	Waterhole[2]	Dawson River[2]		
				WLMP5 2015-2022	DRR1 2015-2022 (upstream)	DRMP1 2015-2022 (downstream)	S4 2015-2022 (downstream)

Rayner et al – analytical method for calculating bioavailable boron
5 – Low reliability percentile due to <70% detection rate

Review of Table 5-20 indicates:

- only aluminium, iron and manganese 95th percentile is above the respective LT in WLMP5, DRMP1 or S4
  - aluminium, iron and manganese are some of the most common naturally occurring metals in the earth crust in the form of aluminosilicates common in clay and iron and manganese as oxides in rocks and soils
- each of these metals are observed in the upstream Dawson River DRR1 at equivalent or higher concentrations, indicating the observed 95th percentile are the result of ambient conditions within the catchment and unrelated to desalinated water releases
- in each of these cases, levels are reduced in the downstream environment relative to the baseline, suggesting GLNG releases as associated with an improvement in sediment quality for the receiving environment
- Aluminium concentrations may also be impacted by sediment particle size
  - DRR1 is located in a pool where lower water velocities allow accumulation of finer sediments (similar to the waterhole) that may have a higher proportion of aluminosilicates
  - DRMP1 is located in a faster run area (Figure 5-3) where coarser sediments appear to be accumulating with a potential lower fine sediment content
- none of the other suite of monitored parameters exceed DGV or LT, suggesting an overall maintenance of good sediment quality for the system.
- An observed increase in boron (bioavailable) 95th percentile concentrations at S4 though concentrations remain below the WQO (based on the SSTL). Review of data indicates that
  - the 95th percentile calculation is based on two detections from eight samples in S4 and this 25% detection rate is below the 30% threshold below which parameters are considered of low concern (per Table 5-9)
  - the 95th percentile value also skewed by a single high value in November 2019 (Figure 5-24)
  - the pattern of elevated boron at S4 did not persist in subsequent REMP data for 2020, 2021 or 2022 being at or below the limit of reporting in all locations since November 2020 indicating an absence of boron accumulation in sediments downstream of desalinated water discharges in the Dawson River
- an observed increase in the 95th percentile of TKN at S4. Review of REMP data indicates the following:
  - the reported TKN 95th percentile for S4 is more reliable (detection rate = 100%) though skewed by a single high reading in May 2021 as can be seen in the time series plot in Figure 5-25.
  - in the majority of REMP monitoring data presented in Figure 5-25 downstream TKN concentrations is below the upstream TKN
  - review using the reference site method (DEHP, 2013; ANZG, 2018) in which site (S4) median levels (115 mg/kg) are compared to the DRR1 80th percentile levels (1,128 mg/L) indicates TKN levels at S4 are not significantly higher than baseline condition.
  - within an agricultural catchment runoff from cattle grazing land and stockyards (located between DRMP1 and S4) can contribute to nutrient loads in surface water.

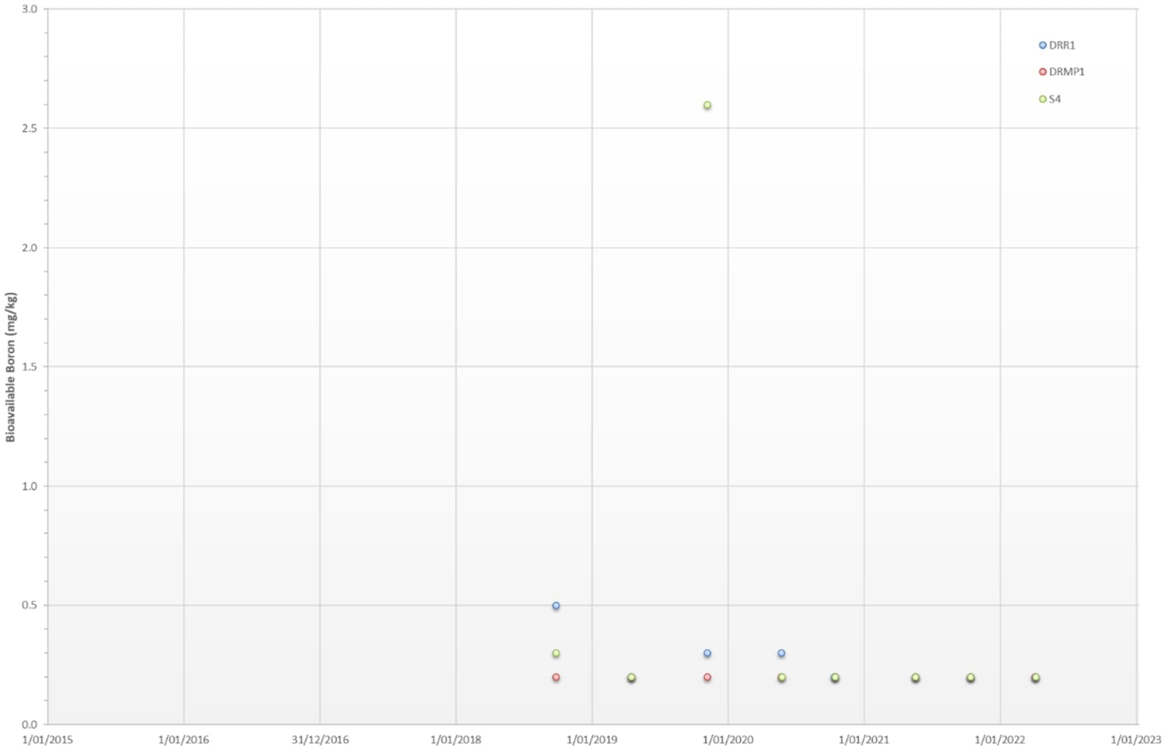


Figure 5-24 **Time series plot of bioavailable boron in sediment in the Dawson River**

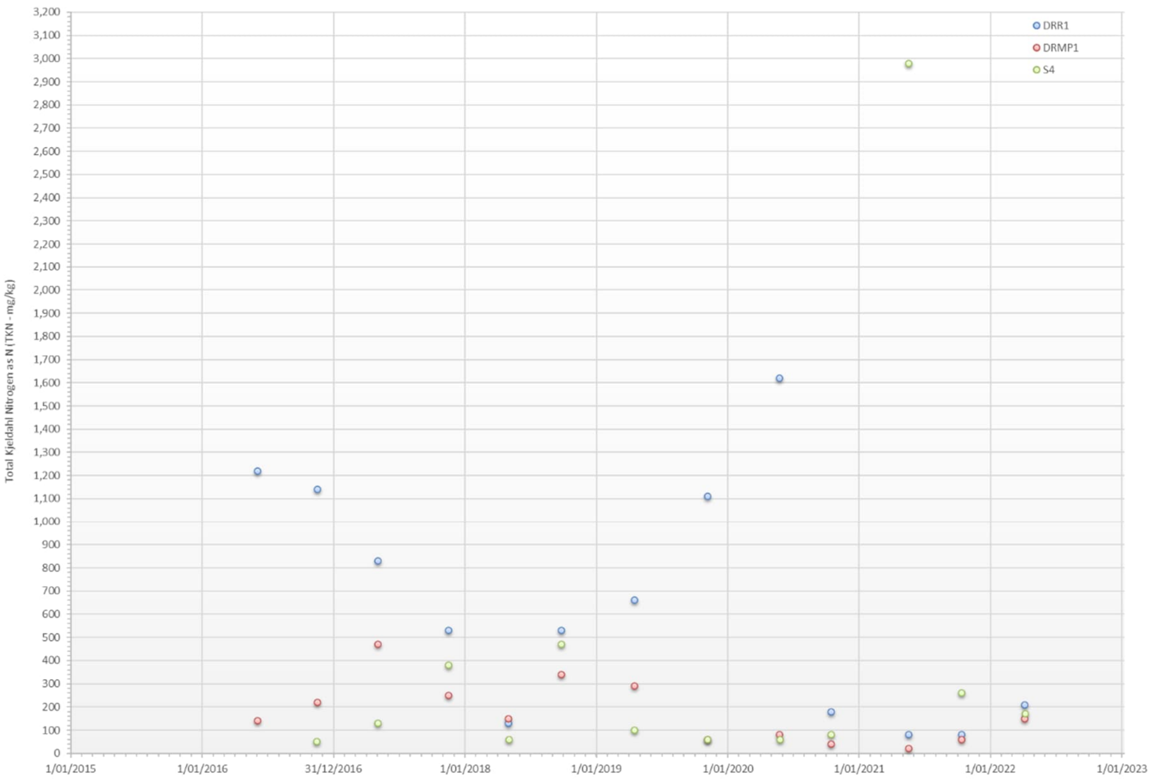


Figure 5-25 **Time series plot of Total Kjeldahl Nitrogen as N in Dawson River Sediments**

In summary, the sediment assessment found no significant evidence of impact downstream of the waterhole confluence as either accumulation of analysed parameters or degradation of sediment quality associated with desalinated water releases. No parameters were detected in exceedance of sediment DGV (ANZG, 2018) in either the baseline, upstream or downstream regions. Of the parameters with no DGV but an LT value derived from baseline monitoring the respective concentrations decrease downstream compared to baseline or the upstream reference location indicating minimal impact from GLNG releases.

For all but two sediment quality parameters, GLNG discharges were actually associated with an improvement in sediment quality. The exceptions were boron and TKN, for each of which the change was assessed as not statistically significant. It is noted that both boron and nitrogen are constituents of fertiliser, however the relative contribution from agricultural runoff cannot be determined from the sampled locations.

5.5 Impact assessment

The proposed action is the release of up to 18 ML/day of desalinated produced water to the Dawson River via the drainage feature, waterhole, and outlet watercourse to the Dawson River. There will be no increase in the existing approved maximum daily release rate (18 ML/day) or total annual volume of 6,570 ML/year. GFD Project water will substitute GLNG Project water, and other water management and beneficial use options such as irrigation will remain in place.

This section assesses the potential impacts to the surface water resource hydrology and quality from the proposed action and responds to DCCEEW and IESC questions summarised at the start of this Section.

5.5.1 Hydrology impact assessment

The release of desalinated water generated from the GFD Project is not expected to change the current hydrological outcomes observed from the current desalinated release data.

As presented in Section 5.2.2.2 the current desalinated release has resulted in a reduction in the ephemeral nature of the drainage feature and waterhole hydrologic regime. Monitoring of the drainage feature channel has not found erosion and sediment deposition to be an issue during operation of the desalinated release. Monitoring of the waterhole bed and bank stability performed under the REMP has not identified any bed or bank stability issues from existing desalinated water releases.

Based on this information the existing armouring of the drainage feature is expected to continue to mitigate potential erosion and sedimentation issues under the proposed action (noting that maintenance works within the drainage feature are approved under State EA conditions if required (refer Appendix D).

Water level monitoring within the waterhole (WLMP1) and Dawson River (S4) (Section 5.2.2.3) indicated an observable increase in water depth of no more than 0.05 m during release cycles under the current desalinated water release at both 13.5 ML/day and 18 ML/day (Figure 5-14 and Figure 5-15). No inundation of the Yebna crossing has been caused by current desalinated water releases under baseflow conditions.

Review of REMP qualitative monitoring records for bed and bank stability (refer to Table 5-1) indicates stable geomorphological conditions within the waterhole and Dawson River under the current desalinated release regime.

Based on review of data collected from existing desalinated water releases, that represent the same conditions for the proposed action, there are no significant adverse impacts to the hydrological regime of the receiving environment.

5.5.2 Water quality impact assessment

The potential impact from changes to water quality from the proposed desalinated water release were evaluated through an assessment of pre-2015 baseline data and REMP monitoring data from 2015 to 2022 for the waterhole and Dawson River, and review against desalinated water quality considered representative of the proposed action.

The proposed action is expected to maintain the current improved waterhole water quality reported in Section 5.3.

Review of REMP data from the Dawson River monitoring locations has not indicated a significant or unacceptable impact or change from upstream reference data or exceedance of applicable WQO (that are not already exceeded upstream) that may be associated with current GLNG Project desalinated water releases from the waterhole to the Dawson River (refer to Section 5.3).

As such, there are no predicted water quality impacts for the continuation of the desalinated release under the proposed action.

5.5.3 Evapo-concentration of key water quality parameters

A review of the proposed action in consideration of representative water quality and hydrology information was performed to identify evidence of evapo-concentration influences on contaminant concentrations.

Potential impact from evapo-concentration of water quality parameters in the waterhole during the proposed action desalinated release is considered low based on:

- Current desalinated water releases maintain perennial water conditions within the waterhole, limiting water level variability (typically to less than 0.5 m) and minimise the opportunity for evapo-concentration of dissolved parameters
- Review of data presented in Section 5.3 and Appendix E-2 does not indicate significant increases in water quality concentrations in the waterhole that may be attributed to evapo-concentration
- The proposed action will assist to maintain the current waterhole water quality (refer Section 5.3.3)

Potential for evapo-concentration of water quality parameters in the Dawson River during the proposed action is considered low based on:

- Review of data presented in Section 5.3 and Appendix E-2 does not indicate significant chemical increases in water quality data that may be attributed to evapo-concentration. Monitoring locations both upstream (DRR1) and downstream of the waterhole confluence (DRMP1 and S4)) reported exceedances above applicable WQOs which are considered to be representative of ambient conditions within the Dawson River
- The baseflow of the Dawson River is perennial at the location the waterhole discharges to the Dawson River and therefore the potential for evapo-concentration in the Dawson River is negligible.

The REMP waterhole and Dawson River water quality data indicated no evidence of evapo-concentration impacts to water quality. Continuation of the desalinated water releases under the proposed action is not expected to be impacted by evapo-concentration.

5.5.4 Sediment quality impacts

The potential impact from changes to sediment quality from the desalinated release were evaluated through current GLNG REMP monitoring data for the waterhole and Dawson River.

Continuing the desalinated release is expected to maintain the current waterhole sediment water quality reported in Section 5.4.

Review of REMP data from the Dawson River monitoring locations has not indicated a significant or unacceptable impact or change from upstream reference data or exceedance of any applicable guideline values that may be associated with current GLNG Project desalinated water releases from the waterhole to the Dawson River (refer to Section 5.4).

Some exceedances of sediment LT values were observed for aluminium, iron and manganese, however, each case these exceedances did not represented a significant impact based on the pre-existing concentrations in the Dawson River upstream reference site DRR1 that are higher for each parameter than downstream values (refer to Appendix E-3).

As such, there are no predicted sediment quality impacts for the continuation of the desalinated release under the proposed action.

5.5.5 Climate change

A qualitative assessment has been performed on the impact from climate change on potential future seasonal and monthly flow regimes in consideration of the proposed action.

Australia’s weather and climate are changing in response to a warming global climate. Australia has warmed on average by 1.44 ± 0.24 °C since national records began in 1910, with most warming occurring since 1950 (BoM, 2020). This is consistent with the global trend with the increase in anthropogenic greenhouse gas (GHG) emissions identified as the main contributor.

The Queensland Government, Queensland Future Climate Dashboard was used to evaluate climate change through evaluation of projected future average temperature, precipitation and evaporation through 2070. The Climate Dashboard is based on the Intergovernmental Panel on Climate Change (IPCC) an international organisation of climate change science experts responsible for modelling potential climate change scenarios for the future and reporting predicted changes that may occur on the global and regional scales. This information is the key source of climate change information used by governments and technical specialists to plan for and management of natural resources such as energy and water in the future. Modelling results are based on the fifth Assessment Report AR5 released in 2014.

The dashboard models were run for the RCP8.5. A Representative Concentration Pathway (RCP) is a greenhouse gas concentration trajectory and RCP8.5 represents a future with little curbing of emissions, with a carbon dioxide concentration continuing to rapidly rise, reaching 940 ppm by 2100. This is a conservative scenario and most closely resembles ‘business as usual’.

Based on the model outputs for the proposed action area, the following changes were predicted for each parameter:

- 3.2-degree Celsius increase in mean temperature
- Less than 0.1 mm/day reduction in annual precipitation, and
- 1.3 mm/day increase in annual pan evaporation

Model outputs are provided in Figure 5-26 through Figure 5-28 below.

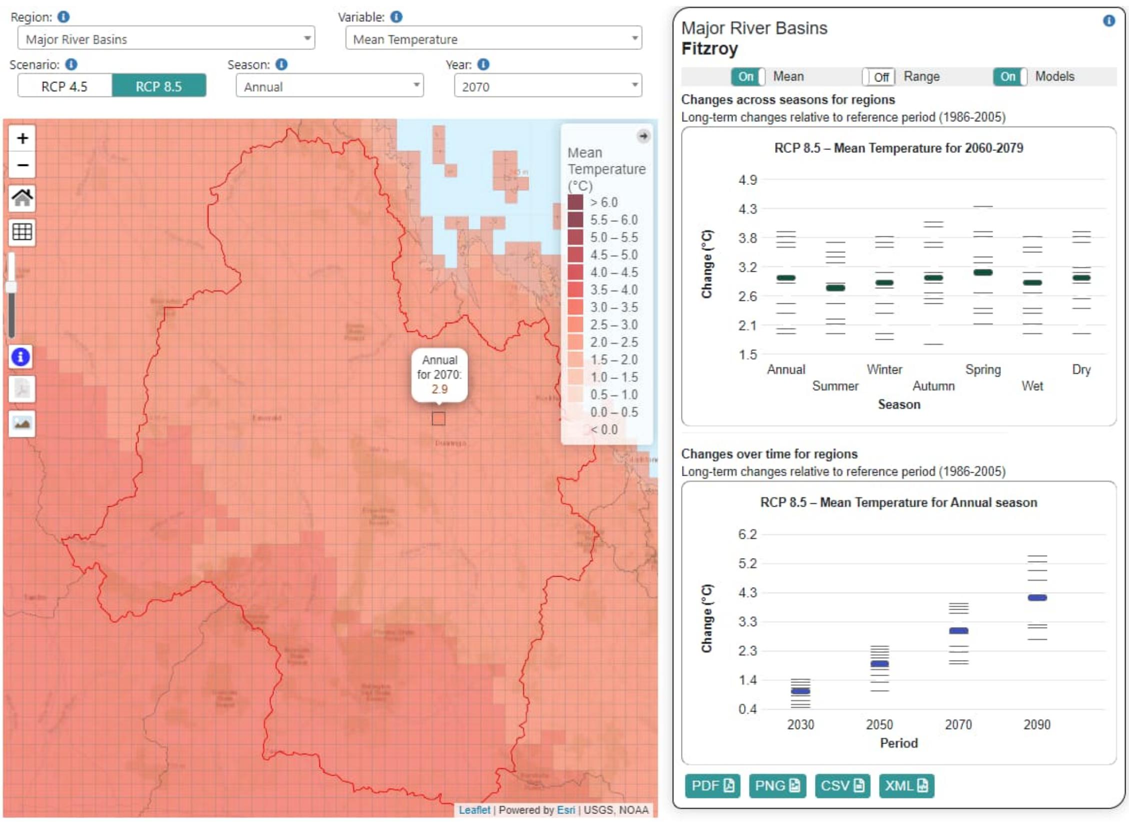


Figure 5-26 Projected change in mean temperature for the Fitzroy Basin

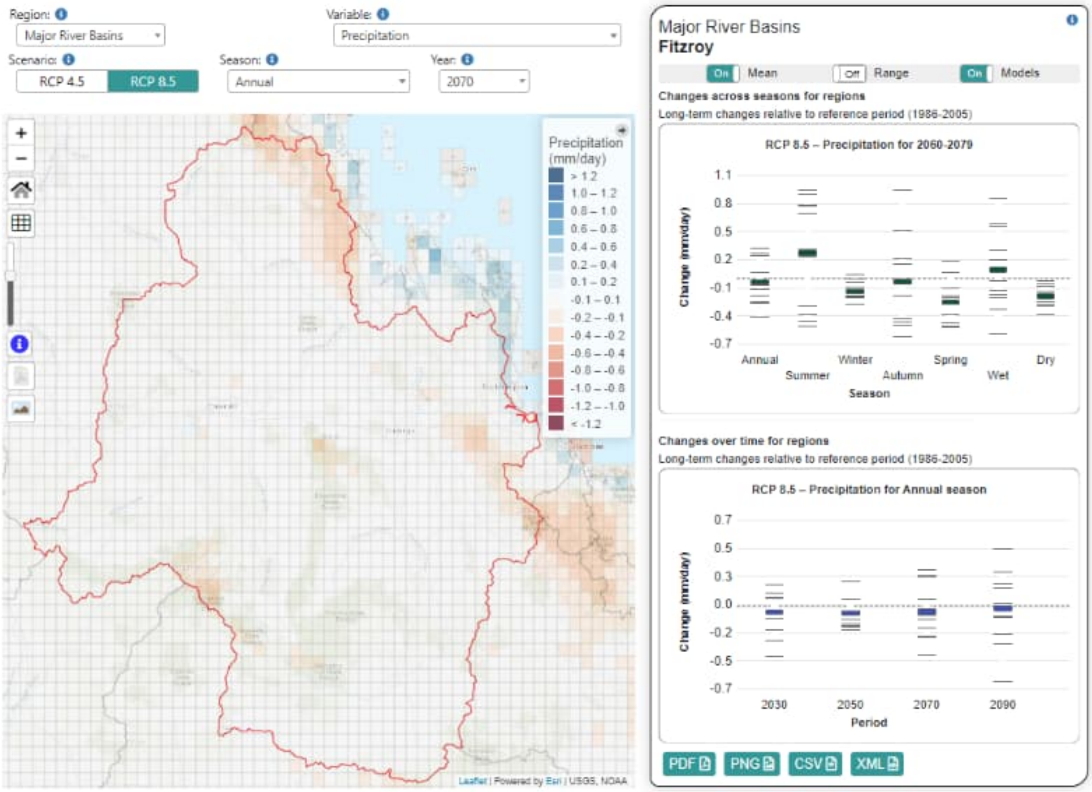


Figure 5-27 Projected change in precipitation for the Fitzroy Basin

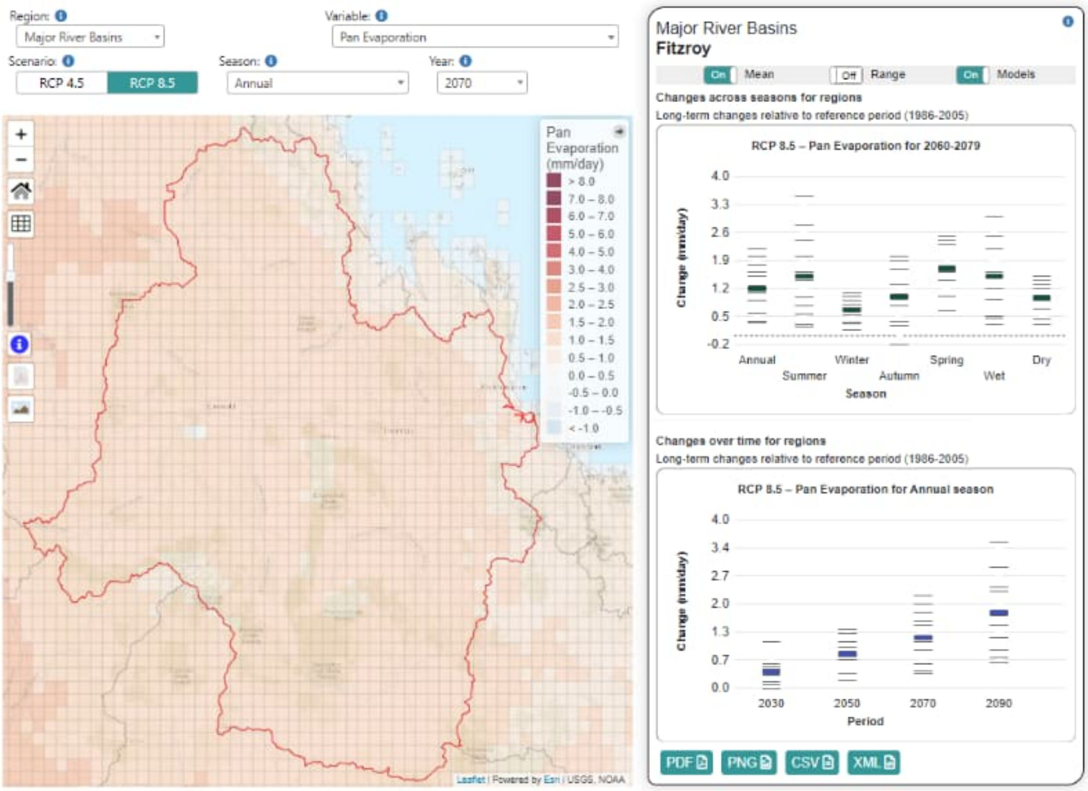


Figure 5-28 Projected change in evaporation for the Fitzroy Basin

5.5.5.1 Drainage feature and waterhole

The drainage feature and watercourse may be subject to de-vegetation and potential for greater erosion in a drying climate without desalinated water releases. In a potentially drying climate, a continuous desalinated water release would maintain current water availability to riparian vegetation and terrestrial GDE utilising the colluvium/alluvium aquifer, maintaining vegetative growth and maintaining bank stability and the downstream ecological, irrigation and human consumer EV for the Dawson River (refer to Table 3-3) providing reliability of water as a resource.

The largest risk to the waterhole from climate change is considered to be the potential for evapo-concentration of parameters based on a predicted increase in evaporation. As discussed in Section 5.5.3, there is no current evidence of evapo-concentration in the waterhole. Since initiation of the desalinated release to the waterhole water levels have been maintained at a higher level, with reductions in overall drying out of the waterhole. Operation of the GFD Project desalinated water release will buffer the waterhole against climatic reductions in precipitation or increases in evaporation.

As stated in Section 5.2.1.1, sections of the drainage feature with erosive potential have already been successfully mitigated under the GLNG Project through armouring placed in high erosion risk areas. Erosion is expected to continue to be more dependent on degradation from cattle access than release, and precipitation under the referenced climate change factors assessed.

5.5.5.2 Dawson River

Baseflow in the Dawson River is expected to be minimally affected by climate change because it is supported by groundwater discharge from the Precipice Sandstone. The groundwater potentiometric surface and gradients of the Precipice Sandstone are not expected to be significantly affected by changes to climate over the lifetime of the project. Therefore, baseflow is expected to be maintained.

Given baseflow is expected to be largely maintained and the maximum rate of desalinated water release into the Dawson River (18 ML/d) is small (0.1%) in comparison with the carrying capacity of the main river channel (16,000 ML/d). Climate change impacts on or associated with desalinated water releases are negligible with respect to baseflow and larger flood flows.

5.5.6 Cumulative impact assessment

Other known petroleum/gas and mining releases to the Dawson River are situated a considerable distance downstream and most are also temporary in nature, occurring during flow events (AECOM 2021 (Appendix A, Section 11.0)

There are no known existing or known potential future projects (e.g., releases to surface water) located upstream of the proposed action.

Regional scale impacts arising from the desalinated water release were assessed (Santos, 2012) using the Integrated Water Quantity and Quality Simulation Model (IQQM) developed by Queensland Department of Environment and Science (DES) (formerly DEHP) for the Fitzroy Water Resource Operations Plan. A conservatively applied constant release of 20 ML/day into Yebna Crossing was modelled in 2012 (prior to finalising actual release requirements). Model outputs were then tested against the Fitzroy Water Resources Plan objectives, i.e., the relevant Water Allocation Security Objectives (WASOs) and Environmental Flow Objectives (EFOs). In general terms, WASOs are water supply security indicators and EFOs include base flow indicators, first post-winter indicators and medium to high flow indicators.

The modelling enabled the following conclusions to be made:

- The inter-annual variations of flows (including flood flows) in the river are largely unaffected by the proposed release. Flooding levels will be unaffected by the ongoing desalinated water release. Baseflow in the Dawson River during desalinated water releases under the proposed action will not increase by more than 0.05 m. There is no observed inundation impact to Yebna Crossing under the GLNG Project desalinated release regime. It is noted that under the revised water release regime commenced in 2021, desalinated water discharge frequency and annual volumes have decreased, as indicated in Table 2-1
- Examination of potential changes in low baseflows indicates that there will be little change in average velocity and river level resulting from the proposed release of desalinated water under the revised water management regime. Observable changes in S4 water levels during low flow

conditions is no more than0.05 m with changes under higher flow being indiscernible in gauging data (Section 5.2.2.3.3).

Cumulative impacts associated with the desalinated water release are considered to be negligible for the following reasons:

- Overall, the release will maintain or improve both WASOs and EFOs
- The overall Dawson River water chemistry will be maintained within current ranges and the rate of release is small in comparison to the carrying capacity of the main river channel. Overall, water quality and hydrological impacts associated with the release are considered negligible
- Other known petroleum/gas and mining releases to Dawson River are situated a considerable distance downstream and most are temporary in nature, occurring during flow events.

5.5.7 Significant impact assessment

As per Significant Impact Guideline 1.3 (DAWE 2013), an action is likely to have a significant impact on a water resource:

> "*if there is a real or not remote chance or possibility that it will directly or indirectly result in a change to:*
>
> - *the hydrology of a water resource*
> - *the water quality of a water resource*
>
> *that is of sufficient scale or intensity as to reduce the current or future utility of the water resource for third party users, including environmental and other public benefit outcomes, or to create a material risk of such reduction in utility occurring.*"

Assessment of potential significant impacts of the proposed action for water resources is based on the information provided in this Section of the PD and where required applicable elements of Section 4.0. A summary of the assessment of the impacts of the event-based release against criteria contained in Significant Impact Guideline 1.3 (DOTE 2013b) is presented in Table 5-21.

For the reasons outlined in the sections above, the proposed action is considered unlikely to directly or indirectly result in a significant change to the hydrological characteristics of a water resource or the water quality of a water resource that is of sufficient scale or intensity as to reduce the current or future utility for third party users, including environmental and other public benefit outcomes, or to create a material risk of such reduction in utility occurring.

Based on the above, it is **unlikely** that the proposed action will result in a significant impact (as defined in Significant Impact Guideline 1.3) to water resources.

Table 5-21 Assessment against significant impact criteria for water resources

Category	Assessment Criteria	Desalinated Water Release	
		Significant impact	Justification
Changes to hydrological characteristics	a) Changes in the water quantity, including the timing of variations in water quantity	Unlikely	Proposed ongoing desalinated water releases for the proposed action will be at a release rate of up to 18 ML/day as required (refer to **Section 2.3**), as limited by the State EA. Based on existing measured water depths, changes in water depth associated with ongoing desalinated water releases, under baseflow conditions where the greatest impacts would be expected are anticipated to be: • no change from the existing water depth range of +0.4 m to -0.5 m within the waterhole • no more than 0.05 m at the Dawson River S4 Gauge based on measured data • measured increases in water depth are slow taking several days to reach the 0.05 m maximum increase under baseflow conditions (compared to same day increases in flow depth in response to rainfall) Hydraulic analyses completed indicate that water level increases are expected to be: • approximately 0.14 m at the waterhole outlet spill point location during desalinated water releases with no change from this under the proposed action. • Generally less than 0.06 m within the Dawson River, near the waterhole – Dawson River confluence. These changes to hydraulic parameters are not considered significant under baseflow conditions, and negligible in flood conditions, and are not expected to result in any changes to geomorphology, aquatic habitat or water quality under the proposed action. Given that changes to hydrological characteristics such as flows, stream hydraulics and geomorphology of the Dawson River are minor to negligible, there is a low risk of impact on the aquatic ecology of the Dawson River associated with the proposed action as a continuation of desalinated water releases.

Category	Assessment Criteria	Desalinated Water Release	
		Significant impact	Justification
	a) Changes in the integrity of hydrological or hydrogeological connections, including substantial structural damage (e.g. large-scale subsidence)	Unlikely	The proposed action is not anticipated to modify the surface water hydrological connectivity associated with the Dawson River, or waterhole from current conditions. Increased water levels within the Dawson River associated with desalinated water releases will not significantly increase (measured as less than 0.05 m at S4) or reverse groundwater flow gradients, such that the Dawson River is always a gaining river at the release point. Based on current conditions, there is no risk of surface water entering the Precipice Sandstone.
	d) Changes in the area or extent of a water resource	Unlikely	The proposed action will maintain the existing volume and extent of water in the waterhole under the proposed action. Changes to the area or extent or water resources within Dawson River are expected to be minor in baseflow conditions, and negligible in flood conditions.
Changes to water quality	d) The ability to achieve relevant local or regional WQOs is materially compromised, and as a result the action:	Unlikely	No significant impact to local or reginal WQO have been identified from the proposed action. No significant risk to human, stock or the natural environment that may be associated with the proposed action based on the following factors • Existing water quality in the Dawson River, including five pre-existing parameters exceeding WQOs, will not be materially changed by the proposed action • A net improvement in water quality and biological indicators in the waterhole will be maintained under the proposed action
	vi. creates risks to human or animal health or to the condition of the natural environment as a result of the change in water quality	Unlikely	
	vii. substantially reduces the amount of water available for human consumptive uses or for other uses, including environmental uses, which are dependent on water of the appropriate quality	Unlikely	The release of desalinated water under the proposed actions does not reduce the amount of water available to downstream users or environmental use in the receiving environment.

Category	Assessment Criteria	Desalinated Water Release	
		Significant impact	Justification
	viii. causes persistent organic chemicals, heavy metals, salt or other potentially harmful substances to accumulate in the environment	Unlikely	Based on an assessment of water quality and monitoring data for water and sediment quality data, the proposed action is unlikely to result in accumulation of chemicals in downstream waters or sediments that may be associated with desalinated water releases. Specific persistent organic chemicals are discussed in Section 8.3 are not considered to pose an unacceptable risk.
	ix. seriously affects the habitat or lifecycle of a native species dependent on a water resource, or	Unlikely	Based on the outcomes of the impact assessment and supported by monitoring data, it is not considered likely that the proposed action will result in a significant change in ecological indicators outside natural variability within the waterhole or Dawson River. Section 6.4 discusses potential impacts to GDE. Section 7.3 discusses potential impacts to MNES turtles
	x. causes the establishment of an invasive species (or the spread of an existing invasive species) that is harmful to the ecosystem function of the water resource.	Unlikely	Based on the outcomes of the impact assessment and supported by monitoring data, it is not considered likely that the proposed action will result in an increase in non-native/exotic species in either the waterhole or Dawson River that are not already present in the Dawson River catchment.
	e) There is a significant worsening of local water quality (where current local water quality is superior to local or regional WQOs)	Unlikely	Based on the outcomes of the impact assessment and supported by monitoring data, it is not considered likely that the proposed action will significantly decrease receiving water quality.
	f) High quality water is released into an ecosystem which is adapted to a lower quality of water	Unlikely	Based on the outcomes of the impact assessment and supported by monitoring data in the receiving environment, that is perennial in nature due to upstream Precipice Sandstone discharges maintaining baseflow conditions, it is not considered likely that the proposed action will significantly impact existing water quality conditions.

<table>
<tr><th rowspan="2">Category</th><th rowspan="2">Assessment Criteria</th><th colspan="2">Desalinated Water Release</th></tr>
<tr><th>Significant impact</th><th>Justification</th></tr>
<tr><td colspan="4">Significant Impact Conclusion
The proposed action is considered unlikely to have a significant impact on groundwater resources as:
• the proposed action is considered unlikely to directly or indirectly result in a significant change to the hydrological characteristics of a water resource or the water quality of a water resource that is of sufficient scale or intensity as to reduce the current or future utility for third party users, including environmental and other public benefit outcomes, or to create a material risk of such reduction in utility occurring.</td></tr>
</table>

5.6 Mitigation and management

The assessment has not identified significant impacts that require implementation of additional monitoring or management measures above existing measures and controls required under the State EA and REMP as summarised in Section 9.0.

Ongoing monitoring of water quality, flow characteristics and abiotic, biotic parameters and ecological and habitat assessments of riverine ecosystem health will be conducted via the REMP. Further details on the REMP are provided in Section 9.0 and Appendix J.

5.6.1 Design

To ensure the potential for environmental harm is minimised, the existing release infrastructure was designed and constructed to ensure WQOs are met within the approved mixing zone of the Dawson River (the distance to the S4 compliance point) and that changes to stream hydrological and hydraulic characteristics are negligible. No new infrastructure is required for the proposed action.

5.6.2 Monitoring

The State EA imposed water quality limits and monitoring conditions. Condition B36 (Appendix D), requires a REMP. The REMP (frc environmental, 2021) is detailed in Appendix J. In response to DCCEEW and IESC comments, Santos proposes the REMP to be implemented as the monitoring plan for the proposed action as provided in Section 9.0.

6.0 Groundwater dependent ecosystems

Chapter summary

Terrestrial GDEs were identified (Queensland State mapping) adjacent to the waterhole and Dawson River within the proposed action area as 11.3.2 - Eucalyptus populnea woodland on alluvial plains including Poplar Box Grassy Woodland on Alluvial Plains as a TEC. The terrestrial GDE 11.3.25 - Eucalyptus tereticornis or E. camaldulensis woodland fringing drainage lines, listed as least concern under the Nature Conservation Act (1992 - QLD) and RE 11.3.19 (*Callitris glaucophylla*, Corymbia spp. and/or *Eucalyptus melanophloia* woodland on Cainozoic alluvial plains), listed as No Concern at present under the Nature Conservation Act (1992) were also present in the proposed action area.

The waterhole is not considered an aquatic GDE based on its reliance on surface water inflows from the surrounding catchment and is not maintained by groundwater from the underlying Evergreen Formation (an aquitard) or the Precipice Sandstone.

The presence of subterranean GDE are generally present in low diversity and abundances and commonly consist of nematodes and copepods from a variety of families within the shallow Precipice Sandstone aquifer generating baseflow and are conservatively considered present in unconfined alluvial aquifers present within and adjacent to the Dawson River.

The proposed release of desalinated water under the proposed action will cause minimal changes on surface water, groundwater or sediment quality either in the waterhole or Dawson River. Similarly, changes to low flow hydrology within the Dawson River (i.e. water depth and velocity) will be minimal. Maintenance of water levels within the waterhole will be improved by maintaining current pool habitat levels through dry periods. The assessment has found that Aquatic, Subterranean and Terrestrial GDEs within the proposed action area are unlikely to be impacted by the proposed action and the applicable EV will be protected under the proposed action. Maintenance of water levels within the waterhole will be improved by maintaining current pool habitat levels through dry periods.

Based on empirical REMP data that have monitored the same proposed releases, the proposed action will not significantly change physical geomorphology or Aquatic and Terrestrial GDE indicating no significant impact via flow rate, water volume or flow depth.

Based on assessment of the proposed action against significant impact guidelines applicable for water resources, it was found that it is unlikely to directly or indirectly result in a significant change to the hydrological characteristics of a water resource or the water quality of a water resource on which a GDE relies that is of sufficient scale or intensity as to reduce the current or future utility or to create a material risk of such reduction in water utility to the GDE.

This section provides the information requested relevant to desalinated water releases (event-based releases are no longer included in the proposed action), within the original RFI (Appendix A), IESC requirements (revised cross-reference table within Appendix C1), and DCCEEW and IESC comments received on the initial PD (response tables within Appendix B2 and Appendix C2 respectively).

DAWE has requested further information to understand the potential for surface and groundwater interactions in the project area and the potential impacts to groundwater dependent ecosystems (GDE). DAWE's request included consideration of both surface water and groundwater impacts to GDEs and aquatic ecosystems within the proposed action area and beyond the project boundary, such as aquatic ecosystems that may be downstream of the proposed action but impacted by the action regardless of proximity to it.

Groundwater and surface water interactions are discussed in detail in Section 4.2. This section addresses the following items from the DAWE RFI, GDE applicable elements of the IESC checklist, and comments from the IESC in 2022, regarding the following:

- The predicted and verified presence of GDE within the proposed action area.
- The potential occurrence of unverified GDE (i.e., those that are suspected to be present but lack conclusive field-based validation in support of their presence).
- A preliminary assessment of potential impacts of the proposed action upon GDE in the proposed action area and downstream.

- Identification of water dependent assets including water dependent flora and fauna and GDE.
- Estimate the ecological water requirements of identified GDEs and other water-dependent assets.
- Describe the process employed to determine water quality and quantity triggers and impact thresholds for water-dependent assets (e.g. threshold at which a significant impact on an asset may occur).

BOOBOOK was engaged by Santos to conduct a literature review and desktop assessment to refine State level GDE mapping for the proposed action area. BOOBOOK also conducted a ground survey to identify the potential presence of, and impact to identified GDEs. The study included review of the following specific datasets:

- Groundwater Dependent Ecosystems Atlas (BoM 2021).
- Remnant vegetation: Regional Ecosystems (RE) – biodiversity status (DES 2021a).
- Queensland Springs Database (Qld Herbarium 2021).
- Groundwater dependent ecosystems and potential aquifer mapping – Queensland (Queensland Government 2021a).
- Queensland Subterranean Aquatic Fauna Database (Queensland Government, 2021b).
- Review of previous BOOBOOK 2020 and 2021 field survey ground truthing RE in the proposed action area.

The key findings of the 2021 supplementary GDE assessments are presented below and can be found in detail in Appendix G. While this section of the PD has been updated to support the revised proposed action (Section 2.0) the project description in BOOBOOK (2021) supplementary assessment was written prior to withdrawal of event-based releases from the proposed action and contains references to event-based releases that are no longer applicable.

6.1 GDE classification

The Australian Bureau of Meteorology's (BoM) Groundwater Dependent Ecosystem Atlas indicates that the proposed action area has a high potential for terrestrial and aquatic GDE.

GDE can be classified into three broad types (Richardson et al. 2011, Doody et al. 2019, IESC, 2019):

- Type 1 – Subterranean – GDE that include aquifer and cave (karst) ecosystems.
- Type 2 – Aquatic – GDE are those dependent on a surface expression of groundwater
    - river baseflow systems – aquatic and riparian ecosystems that exist in or adjacent to streams (including the hyporheic zone) which are fed by groundwater
    - wetlands – aquatic communities and fringing vegetation dependent on groundwater-fed lakes and wetlands, including palustrine and lacustrine wetlands that receive groundwater discharge, and can include spring and swamp ecosystems, and
    - ecosystems that rely on submarine discharge of groundwater for nutrients and/or physicochemical attributes.
- Type 3 – Terrestrial – GDE that are dependent on the subsurface presence and availability of groundwater.

These fundamental definitions are used by both the Queensland DES and IESC within the various environments GDE are encountered.

The IESC (2019) defines groundwater as including water in the soil capillary zone (capillary fringe) but not the water held in the soil above this zone in the unsaturated or vadose zone. Within the saturated zone, pores are filled with water, whereas the capillary fringe and unsaturated zone increasingly have pores containing air as well as water. Perched aquifers in the unsaturated zone are also included as groundwater under the IESC and Queensland DES definitions.

6.2 State mapped GDE within the proposed action area

State mapping (Queensland Government 2021a) and the GDE Atlas (BoM 2021) indicate the possible presence of GDE in the proposed action area (Figure 6-1). These include:

- Aquatic GDE in riverine channels and associated springs with permanent flows supported by Precipice Sandstone groundwater; intermittently flowing riverine channels; and lacustrine and palustrine wetlands on alluvia overlying sandstones. These GDE are mapped with a High to Moderate potential to occur within the proposed action area (Queensland Government 2021a, BoM 2021)
- Terrestrial GDE in the form of treed RE on alluvia are also mapped as present. This GDE is derived from predictive Queensland Wetland mapping (Queensland Government 2021a) in which the State-mapped pre-clearing presence of RE that may contain wetlands, and
- No subterranean GDE are indicated to be present based on State mapping.

State mapping is not always based on actual data within a mapped area but is typically inferred from secondary sources such as satellite imagery.

6.3 Known or likely GDE within the proposed action area

The occurrence of GDE within, and downstream of the proposed action area was further evaluated through ground truthing surveys performed by BOOBOOK in 2020 and 2021, as well as detailed evaluation the hydrogeologic conceptual models and surface water/ groundwater interaction for the waterhole and Dawson River in the proposed action area. The following section summarises the GDE within the waterhole, outlet watercourse and Dawson River.

A conceptual ecohydrological model of potential GDE based on the waterhole to Dawson River cross section is discussed in Section 3.2 and Figure 3-3.

6.3.1 Waterhole and outlet watercourse

6.3.1.1 Aquatic GDE

The waterhole is mapped under Queensland mapping with moderate confidence (Queensland Government 2021a) as an aquatic (Surface Expression) GDE (lacustrine wetland) above a Quaternary alluvial aquifer overlying sandstone ranges (Evergreen Formation). The outlet watercourse connecting the waterhole to the Dawson River is similarly mapped as an aquatic (Surface Expression) GDE (Queensland Government 2021a).

Within the definitions provided in Section 6.1**,** lacustrine wetland GDE are defined as aquatic communities and fringing vegetation dependent on groundwater-fed lakes and wetlands that receive groundwater discharge from underlying geology. Lacustrine wetland GDE are lakes with gaining or variable gaining/losing groundwater connectivity which may be indicated by prolonged lake water availability regardless of surface water availability (Queensland Government 2021a).

Historically the waterhole has displayed ephemeral conditions with large reductions in water area and depth to complete drying (as indicated by historical aerial photography) during dry periods (Santos 2012, AECOM 2016e) (Section 4.2.3.4) in response to short term seasonal to decadal climate fluctuation.

The waterhole and outlet watercourse are not considered to be Aquatic GDEs due to both features being a product of surface water flow from the existing GLNG desalinated water release and surrounding catchment and are not maintained by groundwater. As presented in Section 4.2 groundwater from the underlying Evergreen Formation and Precipice Sandstone is not considered to discharge into the waterhole or the outlet watercourse. Both the waterhole and outlet watercourse are maintained by surface water inflow directly from the surrounding catchment (Figure 4-3) and to a lesser extent the limited Quaternary colluvium and alluvium of the disconnected former Dawson River channel that forms the oxbow lake/waterhole.

On this basis, the waterhole and watercourse are not considered to meet the definition of an Aquatic (Surface Expression) GDE. The waterhole and Quaternary alluvium and colluvium groundwater does support adjacent Terrestrial GDE and is conservatively included in the assessment of impact for desalinated water releases.

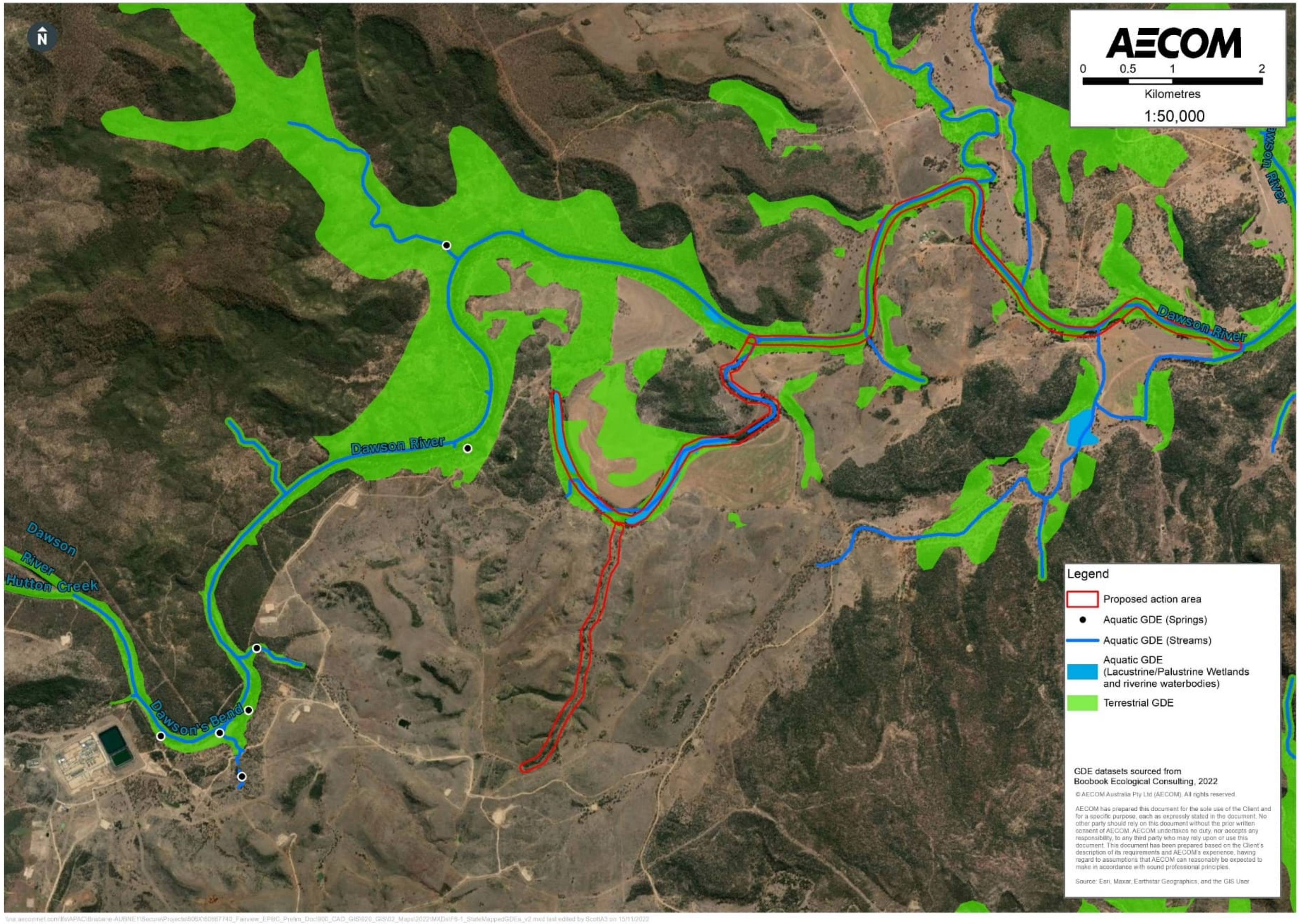


Figure 6-1 State-mapped GDE in and adjacent to the proposed action area (Source: BOOBOOK, 2021; amended AECOM 2022)

6.3.1.2 Terrestrial GDE

State mapping identifies areas adjacent to the waterhole as supporting Terrestrial GDE (Queensland Government 2021a, BoM 2021) based on the mapped (as a mixed polygon) presence of the following RE with a conservation status listing (Figure 6-1**)**:

- 11.3.2 - *Eucalyptus populnea* woodland on alluvial plains
  - Of concern under the Nature Conservation Act (1992 - QLD)
  - A component RE of the listed Poplar Box Grassy Woodland on Alluvial Plains TEC (EPBC Act 1999 - Commonwealth)
  - Poplar Box is a deep-rooted (phreatophyte) species likely to access shallow aquifer groundwater and thus form GDE on floodplains (BOOBOOK, 2021).
- 11.3.25 - *Eucalyptus tereticornis* or *E. camaldulensis woodland* fringing drainage lines
  - Least concern under the Nature Conservation Act (1992 - QLD)
  - A riparian community growing below the high banks of the Dawson River
  - Represented by woodland to open forest of Queensland Blue Gum (*Eucalyptus tereticornis*), River Oak (*Casuarina cunninghamiana*), Rough-barked Apple (*Angophora floribunda*) and Weeping Bottlebrush (*Melaleuca viminalis*), the latter dominating on lower banks (BOOBOOK 2021)
  - Discharge from the Precipice Sandstone is identified as a major source of groundwater supporting the GDE, however inputs of groundwater from alluvial aquifers may also be involved thus the RE in this location can be considered to be a GDE (BOOBOOK 2021).

BOOBOOK (2021) surveys also identified the presence of the RE 11.3.19 (*Callitris glaucophylla*, *Corymbia spp*. and/or *Eucalyptus melanophloia* woodland on Cainozoic alluvial plains), listed as No Concern at present under the Nature Conservation Act (1992). This RE was typically present on sandy levees above the high banks of the Dawson River that are considered to at least periodically access groundwater from shallow alluvial aquifers.

Review of historical aerial imagery indicates the extent of RE 11.3.2 mapped by the State was cleared for agricultural cropping, particularly the alluvial plain northeast of the waterhole between 1997 and 2006.

Field observations by BOOBOOK (2021) in the vicinity of the waterhole indicate that the RE 11.3.2 (*Eucalyptus populnea* woodland on alluvial plains) is of much less extent than shown in State mapping and limited to a small extent at the northern end of the waterhole as shown in Figure 6-2.

Ground-truthing surveys by BOOBOOK in 2020 identified the presence of 11.3.19 (*Callitris glaucophylla*, *Corymbia spp*. and/or *Eucalyptus melanophloia* woodland on Cainozoic alluvial plains) that is likely to represent a Terrestrial GDE. This RE is located on sandy levees above the high banks of the Dawson River. It may at least periodically access groundwater from shallow alluvial aquifers and is likely to be a GDE.

Field mapping and observations by BOOBOOK (2020) identified a small part of the eastern shore of the waterhole and the watercourse between the waterhole and the Dawson River as supporting a narrow fringe of vegetation equivalent to RE 11.3.25 (refer to Figure 6-2). The RE 11.3.25 that exists in this area is more likely to rely on trapped surface water or water stored in the unsaturated zone of the colluvium/alluvium of the waterhole than groundwater within the limited alluvium and colluvium of the waterhole as an oxbow lake as described in Section 4.1.1.4**.**

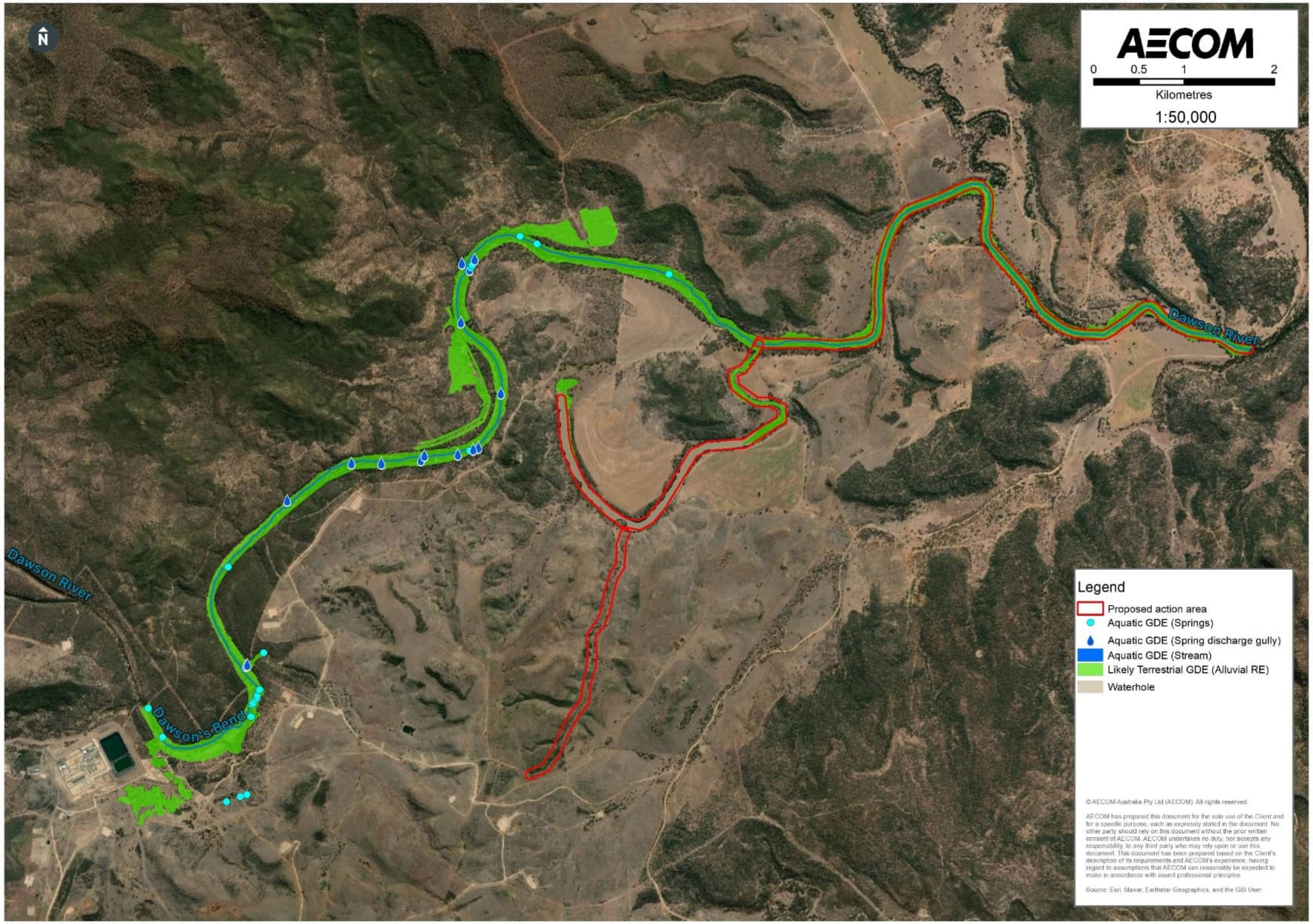


Figure 6-2 Confirmed and likely aquatic and terrestrial GDE in and adjacent to the proposed action area (Source: BOOBOOK, 2021; amended AECOM 2022)

6.3.2 Dawson River

6.3.2.1 Aquatic GDE (surface water expressions)

Within the proposed action area only the Dawson River is considered to be an Aquatic GDE. This conclusion is based on the discussion presented in Section 4.2 with the Dawson River upstream of the proposed action area being fed by the Precipice Sandstone either from springs or directly as baseflow. The aquitard nature and deep water levels within the Evergreen Formation would indicate that the waterhole is not an Aquatic GDE. The Aquatic GDE relevant to the Dawson River is defined below.

Springs are typically located upstream of the proposed action area either on the banks or at a relatively short distance away from the Dawson River, where they connect via spring discharge channels. While the spring flows contribute to riverine GDE values upstream of the proposed action area, they are not located within the proposed action area and their conservation ranking is generally relatively low (Category 2: wetland vegetation without isolated populations) (Qld Herbarium 2021).

Due to the spring inflow and direct baseflow from the Precipice Sandstone, the Dawson River supports a permanent, though variably flowing, freshwater riverine wetland GDE within the proposed action area (DES 2021b). The topography, habitat values, flora and fauna of this reach of the river are well described (e.g., AECOM 2012, frc environmental 2019, BOOBOOK 2021a)). An inventory of 14 native fishes; 6 turtle species, including the critically endangered white-throated snapping turtle (*Elseya albagula*) and vulnerable Fitzroy River Turtle (*Rheodytes leukops*); Platypus (*Ornithorhynchus anatinus*); and a diverse aquatic macroinvertebrate community is known to exist within the in-stream aquatic GDE habitat, where perennial flow occurs (BOOBOOK, 2021).

6.3.2.2 Terrestrial GDE

The Terrestrial GDEs discussed in the following sections have been identified via survey within the proposed action area. Mapped GDEs would be an overestimation, where three often overlapping regional ecosystems are determined to be known or likely terrestrial GDEs and mapped under the general GDE classification in Figure 6-1 and Figure 6-2. It is unlikely that the entire regional ecosystem is reliant on groundwater as part of their water balance, and only individual stands would utilise groundwater.

6.3.2.2.1 Riverine wetland

The Dawson River is mapped under State mapping as supporting a riverine wetland Terrestrial GDE (DES 2021b) of varying width along the length of the Dawson River component of the proposed action area (Figure 6-2). This mapping is based on the riparian community (RE 11.3.25[26]) growing below the high banks of the river. The riparian community RE 11.3.25 is represented by woodland to open forest of Queensland Blue Gum (*Eucalyptus tereticornis*), River Oak (*Casuarina cunninghamiana*), Rough-barked Apple (*Angophora floribunda*) and Weeping Bottlebrush (*Melaleuca viminalis*), the latter dominating on lower banks (BOOBOOK 2021). This RE is classified as “Least Concern” under the *Vegetation Management Act, 1999* (QLD) but has high fauna conservation value, being recognised for high fauna species richness, turtle breeding habitat and foraging and shelter habitat for Koala (*Phascolarctos cinereus*) (DES 2021c).

While discharge from the Precipice Sandstone via springs and baseflow is identified as a major source of groundwater supporting the Terrestrial GDE along the Dawson River upstream of the proposed action area, inputs of groundwater from shallow quaternary alluvial aquifers may also contribute (Queensland Government 2021a) downstream of the Precipice Sandstone. While the riparian community RE (RE 11.3.25), growing on the valley bottom of a perennial stream, can access stream water, it is known that some plants may preferentially draw on shallow groundwater, particularly in gaining rivers, while others can use both sources (Styoecologia 2013). Thus, the RE (RE 11.3.25) located in the Dawson River can be considered a GDE.

6.3.2.2.2 Alluvial plains

Alluvial plains located adjacent to the Dawson River riparian zone but outside the proposed action area (as the channel plus 50 m either side of the Dawson River and waterhole) are mapped as supporting

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[26] 11.3.25 - *Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage lines – Least concern under the QLD Vegetation Management Act (1999).

Terrestrial GDE (Queensland Government 2021a, BoM 2021) as indicated in Figure 6-1. This mapping is dependent on State mapping of RE and is based on the mapped presence of RE 11.3.25 and 11.3.2 (as a mixed polygon), which under State mapping extends to the floodplain areas adjacent to the Dawson River, waterhole, watercourse and the slopes and floors of several smaller valleys containing tributary streams.

The RE 11.3.2 (*Eucalyptus populnea* woodland on alluvial plains) has a Biodiversity Status of "Of Concern" (NC Act) and is a component RE of the listed Poplar Box Grassy Woodland on Alluvial Plains Threatened Ecological Community (TEC) (EPBC Act). Poplar Box is a deep-rooted (phreatophyte) species likely to access shallow unconfined aquifer groundwater and thus form GDE on floodplains (Stygoecologia 2013).

Ground-truthing in the proposed action area includes vegetation assessments by BOOBOOK (2020) in the Expedition Resource Reserve on the northern side of the river, and field observations elsewhere (e.g., BOOBOOK 2021) which indicate that much of the mapped RE identified during ground truthing is not consistent with State mapping (Figure 6-2). In particular, the extent of RE 11.3.2 (*Eucalyptus populnea* woodland on alluvial plains) is much smaller than shown in State mapping (BOOBOOK, 2021). Nevertheless, this RE is confirmed as present in some areas such as the northern and eastern ends of the waterhole (Figure 6-2). It may also have been historically of greater extent within and adjacent to the proposed action area than it is at present, as it was extensively cleared for agricultural purposes, both within the proposed action area and across its wider distribution.

6.3.2.2.3 Alluvial deposits

Ground-truthing (BOOBOOK 2020) identified the presence of a further RE likely to represent a Terrestrial GDE, this being RE 11.3.19 (*Callitris glaucophylla*, *Corymbia* spp. And/or *Eucalyptus melanophloia* woodland on Cainozoic alluvial plains). This RE is located on sandy levees above the high banks of the Dawson River. It may at least periodically access groundwater from shallow alluvial aquifers and is likely to be a GDE (BOOBOOK 2021).

6.3.3 Subterranean GDE

6.3.3.1 Waterhole

The waterhole is underlain by the Evergreen Formation that has been logged as comprising predominantly mudstone and siltstone, with traces of sandstone, with low permeability rates and limited infiltration rates (Section 4.3.1). Due to the limited hydraulic connectivity, overall habitat suitability for stygofauna within the Evergreen Formation is considered to be poor and are therefore unlikely to support stygofauna.

This is considered typical of subterranean GDEs or lack thereof in the Surat and Bowen Basins where low hydraulic conductivity results in no or limited stygofauna (Glanville et al., 2016), Stygoxenic fauna (typically rotifers and nematodes) occur in such poor hydraulic connectivity. These taxa will inhabit groundwater ecosystems like other stygofauna; however, the taxa are not dependent on groundwater ecosystems to complete their lifecycle. These taxa are not obligate inhabitants of groundwater and are unable to establish populations in such systems environments (Glanville et al. 2016) and are not considered to be true stygofauna.

6.3.3.2 Dawson River

A literature review and search of the Queensland Subterranean Aquatic Fauna database (Queensland Government 2021b) failed to find any evidence of investigations into the presence of stygofauna in the Precipice Sandstone. However, stygofauna are known to be present in a wide range of lithologies and environmental parameters (e.g., depth below ground, temperature, salinity, pH) in Queensland (Glanville *et al*. 2016).

Unpublished data collected by Hydrobiology in 2018 from the Precipice Sandstone, approximately ten km downstream of the proposed action area along the Dawson River, indicated that stygofauna are generally present in low diversity and abundances and commonly consist of nematodes and copepods from a variety of families.

Despite this tolerance for a range of environments, taxon richness was positively correlated to lower depths to groundwater, lower salinity, mesic temperatures and neutral to slightly alkaline pH (Glanville *et al*. 2016). Taxonomic richness of eastern Australian stygofauna assemblages is known to be highest in aquifers <10 m below ground, in the alluvium of large rivers tributaries and near phreatophyte trees (plants that obtain water from the groundwater capillary fringe) (Hancock and Boulton 2008).

Some or all of these characteristics are present in the shallow Precipice Sandstone aquifer generating baseflow and unconfined alluvial aquifers present within and adjacent to the Dawson River. Given the noted records of stygofauna downstream of proposed action area and information presented above, it seems likely that subterranean GDE (as stygofauna within the Dawson River alluvium) are present within the proposed action area (BOOBOOK, 2021).

6.4 Impact assessment

The proposed action is the release of up to 18 ML/day of desalinated produced water to the Dawson River via the drainage feature, waterhole and outlet watercourse to the Dawson River. There will be no increase in the existing approved maximum daily release rate (18 ML/day) or total annual volume of 6,570 ML/year. GFD Project water will substitute GLNG Project water, and other water management and beneficial use options such as irrigation will remain in place.

Specific potential impacts raised by DAWE RFI, applicable elements of the IESC Checklist for GDE and received IESC comments as described in Section 6.2 and Section 6.3 relate to the following elements:

- Groundwater drawdown within the Precipice Sandstone and Quaternary Alluvial unconfined aquifer
- Surface water quality degradation associated proposed releases and impacts to GDE and associated water requirements including salinity and general water quality indicators
- Impacts to shallow groundwater resources via proposed releases
- Increased surface water flows, volumes and beneficial uses from proposed releases
- Cumulative risks from combined releases and other projects within the Upper Dawson Catchment

These potential impacts are considered in the following sections along with potential downstream impacts to respective GDEs together with consideration of cumulative impacts and significant impacts to TEC. Impacts to MNES species that rely on such Aquatic GDEs are discussed in Section 7.0 and Section 8.0.

It is important to note that the proposed GFD Project desalinated water releases are consistent with the current GLNG Project releases in terms of volume per release event (as limited by State EA conditions) but at a likely lower frequency and volume per year (subject to climatic conditions) as discussed in Section 2.3. Therefore, the commentary on the data collected as part of the REMP represents impact monitoring and provides information on response/impact (if any) from the proposed desalinated water releases under the GFD Project (i.e. if no response detected currently from GLNG Project then unlikely to detect a response based on the same proposed releases under the GFD Project).

6.4.1 Groundwater drawdown impact assessment

The most frequently cited threat to GDE is the impacts of drawdown of water tables and aquifers (e.g., DES 2021b, Doody *et al*. 2019, Richardson *et al*. 2011). The proposed action is for the release of desalinated water under conditions specified within the State EA (Section 2.3).

6.4.1.1 Waterhole

The proposed action does not include any groundwater abstraction and will not draw down groundwater levels within the unconfined shallow Quaternary alluvium/colluvium associated with the waterhole (refer to Section 4.4.2). Measured water levels in the waterhole vary by up to 0.5 m between release events (Figure 5-5), however these events are intermittent and within the natural range of the historical waterhole range. As such, the proposed action will not impact terrestrial GDE from groundwater drawdown within the waterhole and associated alluvial plain. We note that there are no described Aquatic or subterranean GDEs in the waterhole or outlet watercourse.

Desalinated water releases to the waterhole maintain more consistent water levels within the waterhole (Figure 5-5) and associated groundwater within the shallow quaternary alluvium/colluvium.

6.4.1.2 Dawson River

The proposed action is for the release of desalinated water and will not draw down groundwater levels within the regional Precipice Sandstone aquifer or unconfined shallow alluvial aquifer associated with the Dawson River (refer to Section 4.4.1 and Section 4.4.3).

The proposed action will not impact aquatic GDEs, subterranean GDEs (stygofauna) or terrestrial GDE within the Dawson River from groundwater drawdown.

6.4.2 Surface water quality impact on GDE

6.4.2.1 Waterhole and watercourse GDE

As discussed in Section 6.3.1, the waterhole and outlet watercourse do not meet the definition of an Aquatic (surface expression) GDE, nor is it considered to support Subterranean GDEs. A conservative assessment was applied based on the waterhole supporting adjacent terrestrial GDE to review potential impact from desalinated water releases for the proposed action. The Quaternary alluvium/colluvium adjacent the waterhole supports the following terrestrial GDE:

- RE 11.3.2 - *Eucalyptus populnea* woodland on alluvial plains and
- RE 11.3.25 - *Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage lines.

Water in the shallow Quaternary alluvium/colluvium is considered to be maintained by surface water flow as indicated in Section 6.3.1

Desalinated water meets required sub-regional WQO and State EA CL with the exception of ammonia which, as discussed in Section 5.3.1, is considered to associated with wildlife utilising the DWB pond. The 95th percentile for ammonia in the waterhole is present at lower or similar concentrations than desalinated water (Table 5-12) and (Figure 5-18). Section 5.5.2 has not identified an unacceptable impact to water quality within the waterhole from desalinated water releases. Therefore, changes to water quality are not considered likely to be an issue for the proposed action.

Statistical data (20th, 50th and 80th percentiles) collected during REMP sampling in the waterhole indicated most parameters median concentration decreased between pre-2015 and post-2015 water quality and sediment quality data with the exception of boron. While increases in dissolved boron concentrations are noted in both water and sediment before and after 2015, they have remained below SSWQG. No evidence of impact to Terrestrial GDEs have been noted in the REMP monitoring or distribution within aerial imagery.

Mapped terrestrial GDE RE indicated in Figure 6-1 north of the waterhole is absent in imagery of both before 2015 and after 2015 when desalinated water releases started. Minimal change to riparian vegetation density adjacent the waterhole is evident from aerial imagery between 2006 (Figure 6-3) and 2013 (Figure 6-4) and after 2015 (Figure 6-5) when desalinated water releases started.

REMP monitoring has also indicated physical habitat features within the waterhole was higher than the pre-GLNG baseline condition. Current water levels (and as such associated shallow groundwater levels) have provided a more stable habitat within and adjacent the waterhole.

Based on desalinated water quality and REMP data no significant impact associated with changes to surface water quality or sediment quality have been identified. Therefore, the continued release of desalinated water under the proposed action is unlikely to impact terrestrial GDEs in the vicinity of the waterhole.

6.4.2.2 Dawson River GDE

Section 6.3.2 identified the Dawson River to contain aquatic GDEs (surface water expressions), subterranean GDEs (stygofauna) and terrestrial GDEs.

Desalinated water data for the GLNG Project meets required WQO or are at, or below receiving environment concentrations, as discussed in the previous Section. Therefore, water quality is not considered likely to be an issue for desalinated water discharges.

Assessment of changes to water quality of the Dawson River during GLNG Project desalinated water releases exiting the waterhole (Section 5.3) did not identify significant change in parameters between upstream reference data from DRR1 and downstream DRMP1 data apart from boron, where:

- upstream DRR1 median and maximum concentrations in DRR1 are <0.05 mg/L and
- downstream DRMP1 median and maximum concentrations in DRMP1 are 0.05 mg/L and 0.36 mg/L.

As discussed in Section 5.3 boron concentrations detected during regular REMP monitoring have remained well below both the SSWQG in both water (2.9 mg/L) and sediments (4.0 mg/kg) and the observed slight increase is not considered a significant or unacceptable impact.

Relevant to Aquatic GDEs, aquatic ecological and habitat indicators for the Dawson River reported in REMP monitoring data (Section 5.3.5.3) have not identified significant long term change as discussed in Section 5.3.5.3 and presented in Figure 5-23.

REMP water quality and ecological data within the proposed action area remains within baseline or upstream ranges and is within required LBO, State EA CL or WQO where applicable.

As the water quality has not deteriorated as a result of the desalinated water release to the Dawson River via the waterhole, the Aquatic (surface water expressions), Subterranean and Terrestrial GDEs within the proposed action area are unlikely to be impacted by the proposed action and the applicable EV identified in Table 3-3 will be protected.

6.4.3 Groundwater quality changes and impact to GDE

Potential impacts to GDE in the proposed action area via desalinated water to groundwater chemistry following release is assessed in the following sections.

6.4.3.1 Waterhole and watercourse groundwater and GDE impacts

The waterhole is underlain by the Evergreen Formation that has been logged as comprising predominantly mudstone and siltstone, with trace sandstone, has low permeability rates and infiltration rates are anticipated to be limited (Section 4.3.1).

Downward migration of parameters contained in desalinated water to the underlying Evergreen Formation and Precipice Sandstone is not possible due to the low permeability of the Evergreen Formation and is not considered to result in a significant impact from the proposed action.

As observed in Figure 5-5 measured waterhole levels are pseudo-stable under the current GLNG desalinated water release regime varying by approximately 0.3 m to 0.5 m between periods of desalinated water release. Groundwater within the shallow Quaternary alluvium/colluvium is considered to be maintained by surface water as indicated in Section 4.2.4. Groundwater quality within Quaternary alluvium/colluvium will reflect waterhole conditions under the current release conditions.

As discussed for surface water in Section 6.4.2.1 REMP monitoring has not identified unacceptable impact to the terrestrial GDE present in the vicinity of the waterhole and this may be inferred to reflect the same conclusion for groundwater quality impacts based on the Quaternary alluvium/colluvium aquifer connectivity with the waterhole.

6.4.3.2 Dawson River groundwater and GDE impacts

The Dawson River is a gaining stream due to inflows of groundwater from the Precipice Sandstone via both surface springs (GDE) and direct discharge as baseflow. Desalinated water releases enter the Dawson River downstream of the transition from Precipice Sandstone to the Evergreen Formation (Figure 4-2) and have no impact to the Precipice Sandstone groundwater gradient.

REMP monitoring of the Dawson River habitat, that includes the aquatic GDE and associated alluvial GDE has not detected significant change within Dawson River monitoring locations as discussed in Section 6.4.2. Subsequently no significant or unacceptable impact to GDE within the Dawson River is detected under current or proposed water releases associated with the proposed action.

It should also be noted that current information investigating the toxicity of contaminants (Canivet et al., 2001; Hose et al., 2016, 2019; Reboleira et al. 2013) have shown that stygofauna are more tolerant to acute and chronic exposure and therefore guidelines used for surface dwelling species are likely to be conservative and protective of stygofauna as stated in the ANZG (2018).

6.4.4 Increased water volumes and flow impact on GDE

6.4.4.1 Waterhole flow impacts and changes to GDE

GDE

Prior to the advent of the desalinated water releases in 2015, the waterhole was considered to be ephemeral with highly variable seasonal water extent that in turn resulted in intermittent connectivity with the Dawson River during periods during extreme flows as discussed in Section 4.2.3.4.

Discharge from the waterhole to the Dawson River occurs at variable rates depending on the net balance between rainfall inflow from surrounding drainage features, evaporation and evapotranspiration from flora (Section 5.2.2.2). Before 2015 the waterhole displayed a high level of variability of water content as observed from available aerial imagery as observable in Figure 6-3 to Figure 6-5, consistent with seasonal rainfall cycles.

Since the start of desalinated water releases in 2015 the waterhole has been maintained at a stable water level as a perennial surface water fed wetland with reduced water depth variability compared to pre-2015. Groundwater within the adjacent Quaternary alluvium/colluvium is considered to be connected to and recharged predominantly by surface water inflow to the wetland and occasional Dawson River flood flow.

Section 6.3.1.2 identifies two terrestrial GDE present in the vicinity of the waterhole that are likely to utilise shallow groundwater within the Quaternary alluvium/colluvium, namely *Eucalyptus populnea* woodland on alluvial plains (RE 11.3.2) and *Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage lines (RE 11.3.25).

No evidence of impact to these GDE appears in REMP monitoring data or distribution within aerial imagery. Mapped terrestrial GDE RE indicated on the alluvial plain in Figure 6-1 north of the waterhole is absent in imagery of both pre-2015 and post post-2015 following historical clearing by the landholder in the early 2000's. Minimal change to riparian vegetation density adjacent the waterhole is evident from aerial imagery between 2006 (Figure 6-3) and 2013 (Figure 6-4) and post-2015 conditions (Figure 6-5).

Primary impact to the GDE *Eucalyptus populnea* woodland on alluvial plains (RE 11.3.2) and *Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage lines (RE 11.3.25) appear to be from the early 2000's clearing by the landholder and not associated with desalinated water release to the waterhole and associated Quaternary alluvium/colluvium.

Both BOOBOOK (2021) and frc environmental (2019) conclude that desalinated water releases have contributed to more stable and enhanced conditions at and within the vicinity of the waterhole and associated GDE. This may be attributed to more stable groundwater conditions within the Quaternary alluvium/colluvium.

Waterhole Habitat

Overall habitat value within the waterhole is considered to be improved as a beneficial impact of desalinated water releases. frc environmental (2019) states that the physical habitat features of the waterhole display an increased submerged aquatic plant cover compared to baseline pre-release data. During the BOOBOOK (2021) survey in July 2021, it was observed that the upstream end of the waterhole (northwest) was largely covered by submerged and emergent macrophyte beds, while downstream (east) of the drainage feature entry the waterhole was deeper, with macrophyte beds confined to the margins.

REMP monitoring has identified an increase in native fish abundance within the waterhole since 2015 compared to pre-2015 conditions (Table 5-14) with a net reduction in recorded exotic species from 2017 onwards. Fish abundance prior to 2015 under ephemeral conditions was four species increasing to between 6 and 10 species between 2017 and 2021 under perennial conditions (Section 5.3.4). It is likely that fish have migrated from the Dawson River to the waterhole via the outlet watercourse or during occasional large flood events that overtop the upper banks of the Dawson River and inundate the alluvial plain and waterhole.

Baseline surveys of the waterhole completed before 2015 did not identify the area as critical turtle habitat as discussed in Section 7.2. A single white-throated snapping turtle sighting during GLNG Project REMP monitoring was considered an opportunistic event for this species (refer to Section

7.1.1.4), though MNES turtles may use environments like the waterhole to a greater degree than currently understood as discussed in Section 7.1.2.

Figure 6-3 Waterhole 1997, pre-GLNG (Source DNRM QImagery)

Figure 6-4 Waterhole 2013, pre-GLNG (Source: Google Earth)

Figure 6-5 Waterhole 2018, post-GLNG (Source: Santos)

6.4.4.2 Dawson River flow changes and impacts to GDE

The Dawson River within the proposed action area is a perennial stream with variable flows. Baseflow is consistent but periodically increases rapidly in response to rainfall and often experiences high-energy flood events. Figure 5-10 indicates that gauged water levels at S4 (Yebna Crossing) display an average baseflow of 11 ML/day (0.3 – 0.4 m flow depth) up to 60,000 ML/day (9.1 m flow depth).

Flow Depth

Measured increases in water depth at S4 at the downstream limit of the proposed action area are no more than 0.05 m at both 13.5 ML/day (Figure 5-14 and 18 ML/day (Figure 5-15) desalinated water release rates under baseflow conditions where potential impacts to GDE may be greatest. Calculations presented in Table 5-5, show a 0.06 m increase in the Dawson River water depth at DRMP1 under baseflow conditions (consistent with measurements at S4) to 0.01 m under high flow conditions. The calculated and measured increase in water depth under the baseflow and low flow conditions are contained below the first bench in the banks of the Dawson River.

REMP monitoring within the Dawson River below the waterhole discharge to the Dawson River has not identified significant change in physical geomorphology or aquatic and terrestrial GDE (Section 6.4.2.2**)** indicating no significant impact from desalinated water releases via flow rate, water volume or flow depth changes since 2015. Similarly, no impact is expected with the proposed action which will continue in the same manner as current desalinated water releases.

Erosion Risk

Potential riverbank erosion risks from desalinated water releases under baseflow conditions have not been identified based on observed REMP records and measured flow depth changes no more than 0.05 m and occurring over a number of days (Section 5.2.2.3.3). Existing REMP monitoring indicates current desalinated water releases from the waterhole have not resulted in apparent changes to riverbank erosion outside natural limits or aquatic GDE within the Dawson River.

Based on measured REMP data at both 13.5 ML/day and 18 ML/day release rates no significant impact was identified to GDE, associated lifecycles, or fauna and flora movement.

6.4.5 Downstream impacts on GDE

Impact assessment potential changes in water quality (Section 6.4.2), potential changes in groundwater quality (Section 6.4.3) and potential water volume and flow changes (Section 6.4.4), together with REMP data indicated no significant or unacceptable impacts to aquatic GDE or Terrestrial GDE within the proposed action area. Consequently, in the absence of indicators of impact within the proposed action area, no significant impact to downstream aquatic GDE or terrestrial GDE are expected.

6.4.6 Cumulative impact assessment

A cumulative impact assessment was undertaken to assess potential cumulative impacts resulting from the proposed action, including known existing and known potential impacts.

There are no known existing or known potential future projects (e.g., releases to surface water) located upstream of the proposed action area. The landholder operating adjacent the proposed action area holds a license to extract water from the Dawson River of up to 240 ML per annum and no more than 9.9 ML/day when flow rates in the Dawson River exceed 20 ML/day (Section 3.3). The extent to which the license is utilised is not known, however, REMP monitoring does not identify any change in GDE that may be associated with water use under or combined with the existing water allocation.

As described in Section 2.2 and Section 2.3 the proposed action will continue based on current water management procedures that prioritises beneficial reuse and intermittent release of desalinated water via existing treatment and release infrastructure. Predicted produced water volumes will steadily decline over the duration of the proposed action and will not result in an additional burden or load on GDE present in the proposed action area.

As such, no significant cumulative impact has been identified to terrestrial GDE, aquatic GDE or subterranean GDE from the proposed action.

6.4.7 Significant impact assessment

Potential for Significant Impact on GDE within the proposed action area due to the release of produced desalinated water to the Dawson River were assessed using the EPBC criteria for Significant Impacts on MNES (DoE 2013) noting that GDE are not specifically referenced in SIG 1.1 or SIG 1.3 but may be assessed via SIG 1.3 as a water dependent resource.

As per Significant Impact Guideline 1.3 (DAWE 2013), an action is likely to have a significant impact on a water resource:

> "*if there is a real or not remote chance or possibility that it will directly or indirectly result in a change to:*
>
> - *the hydrology of a water resource*
> - *the water quality of a water resource*
>
> *that is of sufficient scale or intensity as to reduce the current or future utility of the water resource for third party users, including environmental and other public benefit outcomes, or to create a material risk of such reduction in utility occurring.*"

The potential impact on Aquatic GDE and Terrestrial GDE as a result of changes to groundwater availability or quality or surface water quality and flow is considered **unlikely**. This was confirmed with the EPBC significant impact assessment resulting in no significant impact (Table 6-1).

Table 6-1 Assessment against significant impact criteria

Significant Impact Criteria[A]	Significant impact	Justification
reduce the extent of an ecological community	Unlikely	The proposed action is seeking to continue existing intermittent desalinated water releases and does not include any direct clearing of vegetation. The assessment has not identified significant impacts to groundwater resources, surface water resources (flow and/or quality and/or water availability) that will result in an adverse effect to the extent of ecological communities within the proposed action area or downstream. No significant change from current surface water or groundwater or monitored ecological indicator conditions is evident in data and as such the proposed action is unlikely to reduce the extent of the ecological community through degradation in environmental conditions.
fragment or increase fragmentation of an ecological community, for example by clearing vegetation for roads or transmission lines	Unlikely	The proposed action is seeking to continue pre-existing desalinated water releases that have occurred since 2015 and does not include clearing of vegetation or disruption of habitat for ecological communities. An overall net maintenance and improvement in ecological community metrics have been recorded in the waterhole as a result of existing and continued desalinated water releases as recorded in REMP data.
adversely affect habitat critical to the survival of an ecological community	Unlikely	The assessment has not identified significant impacts to groundwater resources, surface water resources (flow and quality) or direct habitat disturbance that will result in an adverse effect to habitat critical to the survival of the ecological community. No clearing of GDE is proposed and no indirect impacts GDE are expected under the proposed action.
modify or destroy abiotic (non-living) factors (such as water, nutrients, or soil) necessary for an ecological community's survival, including reduction of groundwater levels, or substantial alteration of surface water drainage patterns	Unlikely	Assessment of the proposed action has not identified significant long-term changes in ecological community structure within the proposed action area outside pre-existing natural variation. Assessment of the proposed action has not identified significant changes to existing groundwater or surface water quality determined that impacts are unlikely and the degradation of water quality and alteration to the groundwater gradient is unlikely. The action is unlikely to result in the reduction of groundwater levels, or substantial alteration of surface water drainage patterns. No indirect impacts to GDE are expected.

Significant Impact Criteria[A]	Significant impact	Justification
cause a substantial change in the species composition of an occurrence of an ecological community, including causing a decline or loss of functionally important species, for example through regular burning or flora or fauna harvesting	Unlikely	Long term monitoring of existing desalinated water releases and as such the future desalinated water releases under the proposed action have not identified a significant change of ecological communities outside existing range and variability. Observed long term increases in abundance and diversity in the waterhole are local and not considered large in area or scale. The waterhole is not identified as critical habitat for MNES species but does provide increased refuge opportunity. As such the action is not expected to cause a substantial change in species composition of the ecological community. No clearing of GDE is proposed and no indirect impacts GDE are expected from the proposed action.
cause a substantial reduction in the quality or integrity of an occurrence of an ecological community, including, but not limited to: • *assisting invasive species, that are harmful to the listed ecological community, to become established, or* • *causing regular mobilisation of fertilisers, herbicides or other chemicals or pollutants into the ecological community which kill or inhibit the growth of species in the ecological community, or*	Unlikely	As a continuation of existing desalinated water releases, the proposed action will not exacerbate existing threats from invasive species beyond already existing levels recorded for the upper Dawson River catchment. Desalinated water currently released under the GLNG Project achieves required WQO and CL with the exception of ammonia which is within baseline levels for the waterhole or below upstream levels recorded in the Dawson River. Current (and ongoing) levels of parameters in released desalinated water has not resulted in significant changes in the ecological communities of receiving waters and environment outside existing seasonal and decadal seasonal variation.
interfere with the recovery of an ecological community	Unlikely	The action is unlikely to interfere with the recovery of the ecological community within or downstream of the proposed action.

Significant impact conclusion

The proposed action is considered **unlikely** to have a significant impact on groundwater resources based on:

- the proposed action is considered unlikely to directly or indirectly result in a significant change to the hydrological characteristics of a water resource or the water quality of a water resource on which a GDE relies that is of sufficient scale or intensity as to reduce the current or future utility or to create a material risk of such reduction in water utility to the GDE.

[A] As specified in Significant Impact Guideline 1.1 (DAWE 2013a).

6.5 Mitigation and management

The proposed action is seeking to continue existing produced water management releases to the Dawson River for water generated by the GFD Project. Current measures and operational controls for the release of desalinated water are specified in the State EA together with Santos operational and management controls for the existing GLNG Project.

The assessment has not identified significant impacts that require implementation of additional monitoring or management measures.

Ongoing monitoring of water quality, flow characteristics and abiotic and biotic parameters of riverine ecosystem health will be conducted via the REMP. Further details on the REMP are provided in Section 9.0 and Appendix J.

7.0 MNES turtles

Chapter summary

The Dawson River within, upstream and downstream of the proposed action area provides critical habitat for white-throated snapping turtle (critically endangered) and Fitzroy River turtle (vulnerable), noting that critical habitat for both species occurs throughout their full respective ranges within the Upper Dawson River catchment.

The proposed release will cause minimal changes on water quality, including key parameters such as dissolved oxygen and suspended solids that are important parameters for cloacal respiration by these turtle species.

Similarly, changes to low flow hydrology (i.e. water level and velocity) will be minimal and do not increase risk of nest inundation during low flows or adversely impact foraging and residing habitat quality. Changes to high flow hydrology are not distinguishable from natural conditions.

The principal threat to both species of turtle is nest predation by introduced pigs, cats and foxes, with pig damage known along the banks of the Dawson River and trampling of nests by cattle that are outside the influence of the proposed action.

The proposed releases will not exacerbate threatening processes nor cause a significant impact to turtles.

Two of the six freshwater turtles identified to be present within the proposed action area are MNES species: the white-throated snapping turtle (*Elseya albagula* – listed as critically endangered) and Fitzroy River turtle (*Rheodytes leukops* – listed as Vulnerable). DAWE requested additional assessment of potential impact to habitat for the two identified species, together with confirmation of sighting records and assessment of potential water quality impacts.

BOOBOOK was engaged by Santos to conduct a literature review and field survey to address aspects of the DAWE request.

Results of the literature review and field survey are summarised in this section to provide information for the following items from the DAWE Information Request:

- The known historical distribution (i.e., location records) of the two turtle species
- The occurrence of the two species within and upstream of the proposed action area
- The terrestrial and aquatic environment suitable to support their habitat requirements
- Aspects of water quality suitable to support their habitat requirements
- Estimated areal extent and mapping of suitable foraging, shelter and breeding habitat within and upstream of the proposed action area
- The potential impacts of the proposed action on the habitat, including hydrology (flow rates, water levels, bank stability), sediment and contaminant effects, and
- Avoidance and mitigation measures.

BOOBOOK (2021) undertook field surveys to collect additional data between 14 July and 19 July 2021 within and upstream of the proposed action area. Additional detail and photographs from the field survey can be found within the BOOBOOK (2021), Dawson River Turtle Habitat Impact Assessment Report provided in Appendix G. While this section of the PD has been updated to support the revised proposed action (Section 2.0) the project description in BOOBOOK (2021) Turtle Habitat Impact Assessment Report was written prior to withdrawal of event-based releases from the proposed action and contains references to event-based releases that are no longer applicable.

7.1 Habitat assessment

7.1.1 Population distribution and site records

7.1.1.1 White-throated snapping turtle desktop review

The white-throated snapping turtle is predominantly found in permanent waters of the Burnett, Mary and Fitzroy Rivers and their associated tributaries, and in nearby coastal waterways (e.g. Kolan and Burrum Rivers). However, there are also some records of the species from isolated waterholes in non-permanent reaches of the Burnett River and in some tributaries of the Fitzroy River.

A phylogeographic study (Todd 2013; Todd et al. 2014) indicated that the population of white-throated snapping turtle from the Fitzroy Basin (as a whole) was distinct from the populations in the Mary, Burnett and Kolan Rivers, but white-throated snapping turtle from the Dawson River were not genetically distinct from elsewhere in the Fitzroy River Basin.

The white-throated snapping turtle is known to occur throughout the Fitzroy catchment from the Fitzroy Barrage upstream to the highest spring-fed pools in the Mackenzie and Dawson Rivers. The western-most records of the species are in the Nogoa River at Emerald and at Carnarvon Creek, a tributary of the Comet River (ALA 2021).

Limpus et al. (2011) reported that within the Dawson River individuals were recorded from permanent waters as far upstream as the properties "Warndoo" on Hutton Creek and "Korcha" on the Dawson River, upstream of the proposed action area. The species was reported (DES 2021, ALA 2020) from Baroondah Crossing on the Dawson River in 1979 and frc environmental (2010) recorded the species in the Nathan Gorge, also upstream of the proposed action area. In a rapid survey of around 45 km of potentially suitable habitat on Eurombah Creek (a major southern tributary of the upper Dawson River), the species was detected in 17 of 45 surveyed waterholes (38%) and it was concluded that it was likely to be present in all suitable habitat in the proposed action area and vicinity (BOOBOOK 2017).

The known distribution of white-throated snapping turtle is illustrated in Figure 7-1.

7.1.1.2 White-throated snapping turtle field observations

The baseline monitoring program for the REMP regularly caught white-throated-snapping turtle in Hutton Creek and the Dawson River upstream of the proposed action area (frc environmental 2015). Monitoring of turtles since 2015 (implemented in conjunction with REMP monitoring) has indicated the presence of white-throated snapping turtles on multiple occasions in Hutton Creek and the Dawson River upstream of and within the proposed action area, as well as a single record from the waterhole downstream of the desalinated water release location (frc environmental, 2019a; frc environmental unpublished data).

The habitat type where white-throated snapping turtles were caught on these surveys was pool habitat in Hutton Creek (located upstream of the proposed action area) and pool and run/ glide habitat in the Dawson River. Incidental observations at pools in the Dawson River during ecological surveys in 2019-2020 (BOOBOOK 2020) identified the white-throated snapping turtle at four locations at and below the junction of Hutton Creek and the Dawson River. During a more recent survey (BOOBOOK 2021) turtles were observed at a further two locations in the Dawson River within the proposed action area.

The multiple surveys and cumulative records to date indicate that the white-throated snapping turtle is present upstream of the proposed action area based on observations in Hutton Creek, throughout the reach of the Dawson River within the proposed action area, and likely occurs only as an occasional vagrant in the waterhole. The cumulative distribution of white-throated snapping turtle sightings within and upstream of the proposed action area between 2013 and 2022 is presented in Figure 7-2**.** The home range of the white-throated snapping turtle is now considered to be over 30 km and the distribution observed under REMP surveys is more likely a product of survey effort rather than actual distribution within the proposed action area; i.e. it is likely present in greater numbers than captured under REMP surveys.

A habitat description for each of the REMP monitoring locations is summarised in Section 7.2.1.

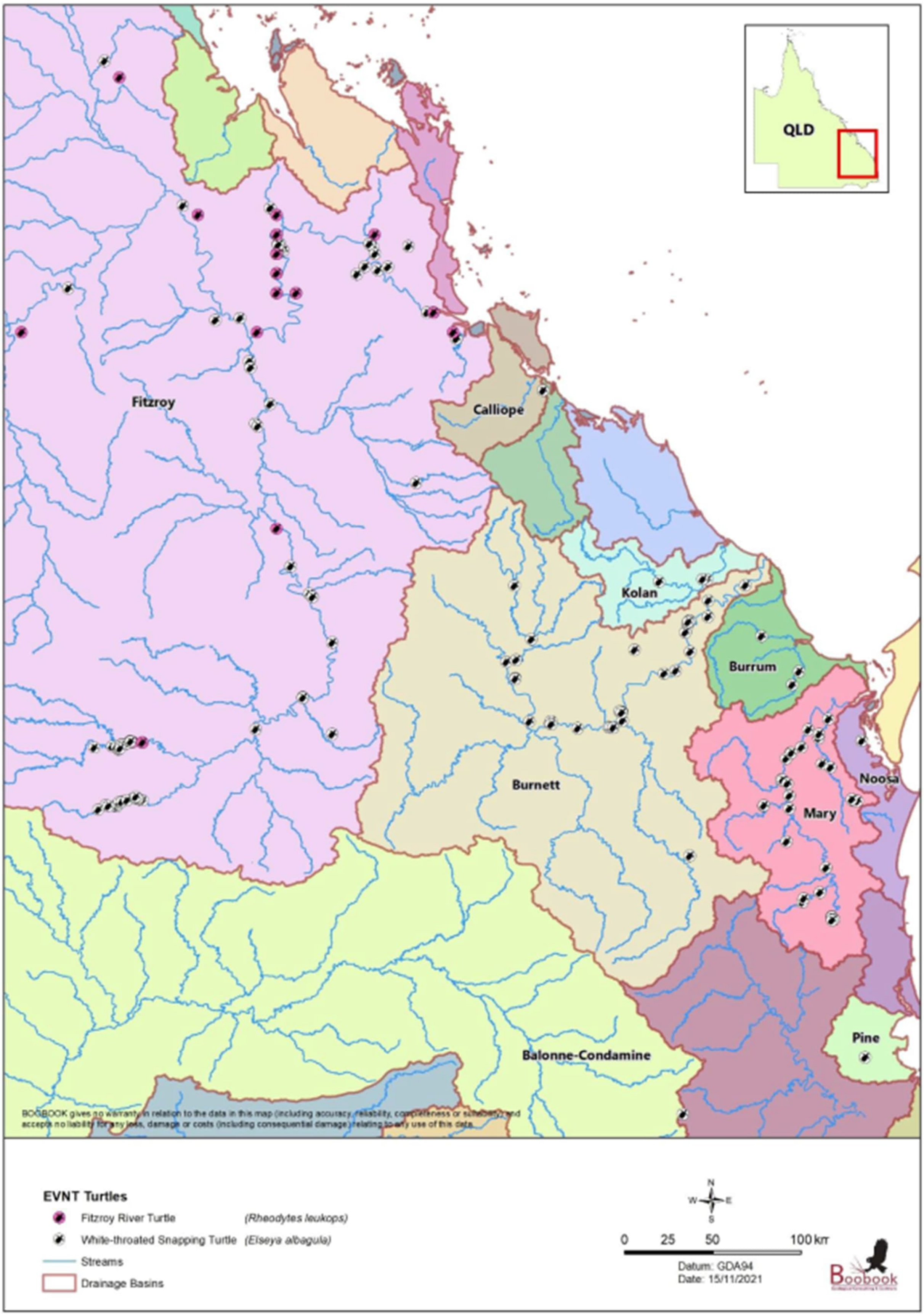

Figure 7-1 Known Distribution of white-throated snapping turtle and Fitzroy River turtle (BOOBOOK, 2021)

7.1.1.3 Fitzroy River turtle desktop review

The Fitzroy River turtle is found only in the Fitzroy River and its associated tributaries. Reported occurrences include the Fitzroy River near Duaringa, Boolburra, Glenroy Crossing and Gogango; Marlborough Creek; Moura, Baralaba, Gainsford and Theodore on the Dawson River; the Mackenzie River near Comet; and the Connors River near Lotus Creek (ALA, 2020, Limpus et al. 2011).

The global distribution of Fitzroy River turtle is illustrated in Figure 7-1.

7.1.1.4 Fitzroy River turtle field observations

Between 2017-2019 the Fitzroy River turtle was recorded at three survey locations on the upper Dawson River, with one of these sites (DRR1) located upstream of the proposed action area and the two other sites (DRMP1 and S4) located within the proposed action area (Figure 7-2) (frc environmental 2018, 2019a).

Suitable riverine habitat for the Fitzroy River turtle occurs in the Dawson River and tributaries (e.g. Hutton Creek) upstream of the proposed action area, and in the Dawson River within the proposed action area (AECOM 2016a; BOOBOOK 2019; frc environmental 2019a). However, the Fitzroy River turtle has not been sighted within the waterhole in surveys completed to date under the GLNG Project REMP, and it is considered that the waterhole does not likely provide essential habitat for Fitzroy River habitat in accordance with the following sections.

The cumulative distribution of Fitzroy River turtle sightings within proposed action area between 2013 and 2021 is presented in Figure 7-2. A habitat description for each of the REMP monitoring locations is provided in Appendix F.

7.1.2 Suitable turtle habitat characteristics

7.1.2.1 Aquatic (shelter and foraging) habitat characteristics

A summary of the aquatic habitat characteristics for the white-throated snapping turtle and Fitzroy River turtle is provided below with a more detailed description in Appendix H.

Fitzroy River turtles are only found in flowing rivers with large deep pools with rocky, gravelly or sandy substrates that are connected by shallow riffle areas. Riffle zones, which only occur in flowing sections of streams and rivers, are an important habitat for the Fitzroy River turtle, with the home ranges of individuals typically including these habitats.

The white-throated snapping turtle and Fitzroy River turtle primarily inhabit a range of habitat including permanent waters of rivers and streams with deep pools permanently or periodically inter-connected by shallow riffles (Hamann et al. 2004, Limpus et al. 2011). Preferred habitat areas for both turtle species have high water clarity (low turbidity and TSS) and are often associated with aquatic plants (TSSC 2008, Hamann et al. 2004, Limpus et al. 2011). Both species are increasingly considered to be present in a wider range of habitat including slow-flowing or still pools with silty substrate and suitable macrophyte cover and have been found in isolated pools not connected by flowing water habitat.

Both white-throated snapping turtle and Fitzroy River turtle are notable for their possession of highly developed cloacal respiration capacity. This physiological adaptation allows them to remain submerged for prolonged periods in well-oxygenated waters.

Occurrence records for the white-throated snapping turtle within and upstream of the proposed action area almost exclusively show close association with permanent flowing stream reaches that are typically characterised by a sand-gravel substrate with submerged rock crevices, undercut banks and/or submerged logs and fallen trees, although there is a single record of the species from the Waterhole.

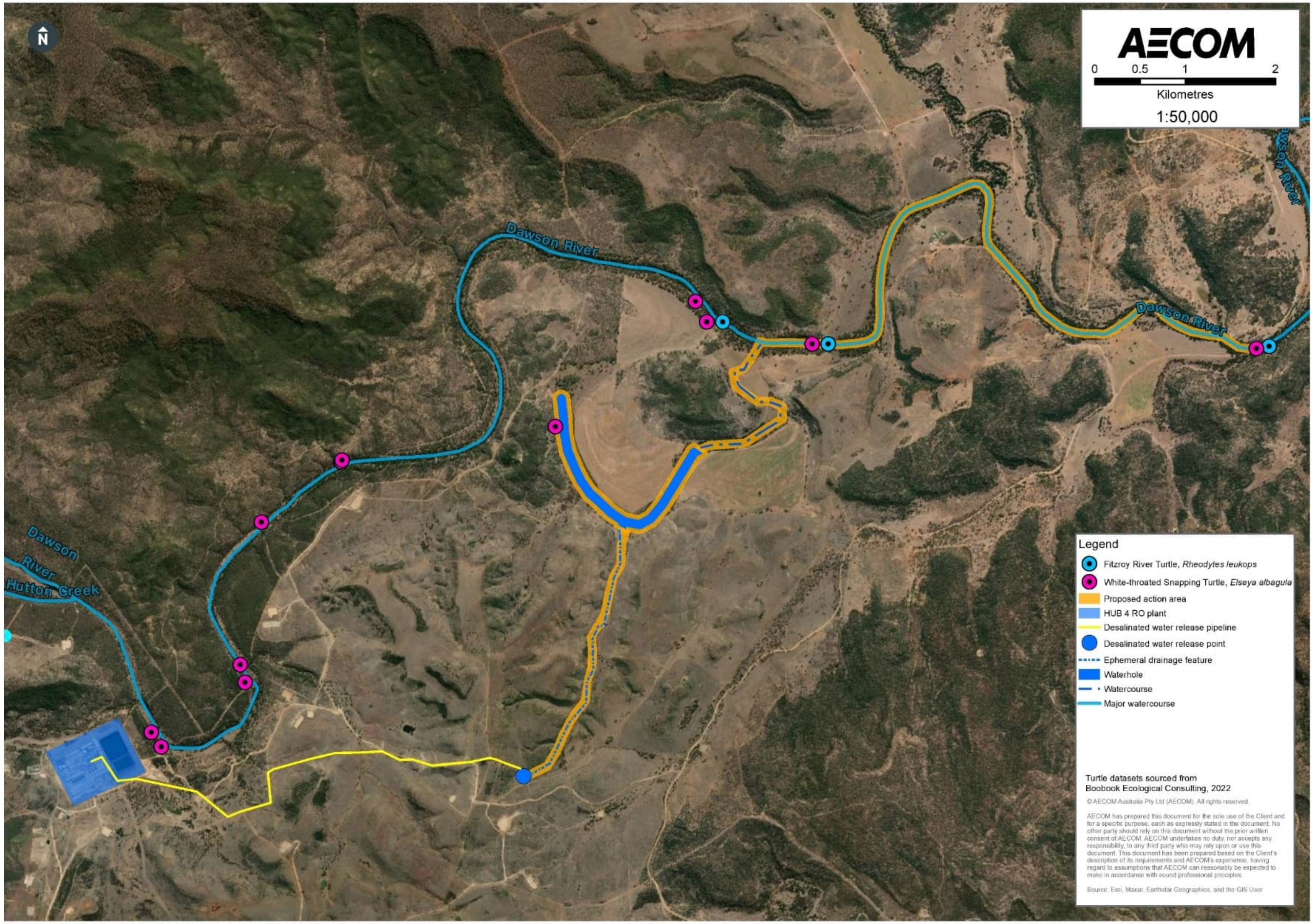

Figure 7-2 Cumulative recorded locations for white-throated snapping turtle and Fitzroy River turtle within and in proximity to the proposed action area (Source- BOOBOOK, updated AECOM 2022)

Both species are known to exploit resource-rich riffle sections of streams (Limpus et al. 2011). Limpus et al. (2011) emphasize the importance of riffles as a foraging habitat for both species at least when these are seasonally available, noting that other resource-rich habitats (e.g. bed of submerged aquatic plants) are also utilised as feeding habitats.

When riffles reduce or dry up with decreasing flows, turtles retreat to deeper pools which can be viewed as refugia. Both species are able to use deeper pools, but these may be of lower productivity than riffle zones, and it is suggested that access to riffles allows populations of the turtles to exist at higher densities than they might if restricted to permanent deep pools (Limpus et al. 2011), noting increased occurrence in slow-flowing or still pools with silty substrate and suitable macrophyte cover.

Faster-moving water in runs, glides and riffles is readily available along the Dawson River within and outside the proposed action area and upstream in Hutton Creek that also receives baseflow from the Precipice Sandstone. Tucker et al. (2001), working in the much more expansive lower Fitzroy River, noted that Fitzroy River turtle preferred riffle habitat (though Limpus et al. (2011) offers a countering position) and the mean distance of tracked individuals from a riffle (with depths <1.1 m) was 310 m. BOOBOOK (2021) concluded that perennial baseflow (sustained by groundwater discharge from Precipice Sandstone) within and upstream of the proposed action area created shallow flowing water habitats that were closer than 310 m, which connected deeper pool habitat even during the dry season.

Though both species are apparently capable of moving across relatively short distances of dry riverine habitat, at least in seasonally favourable conditions (e.g., during rainy weather), although both species occur less commonly in ephemeral waterways and floodplain wetlands, and not known from farm dams (Hamann et al. 2007, Limpus et al. 2011, Commonwealth of Australia 2020).

7.1.2.2 Breeding ecology and nesting habitat characteristics

7.1.2.2.1 White-throated snapping turtle

Published data for white-throated snapping turtle nesting sites in the Mary, Burnett and Fitzroy Rivers (Hamann et al. 2004, Limpus et al. 2011) indicate that a variety of nesting locations may be used. These include in-stream and on-bank flood-deposited sandbanks as well as sandy to loamy soils on riverbanks. Both bare and vegetated substrate may be used.

The white-throated snapping turtle lays a single clutch of eggs (mean clutch size = 14) annually, primarily in autumn-winter though some lay as late as spring, with hatching occurring in December-January (Limpus et al. 2011, Commonwealth of Australia 2020). Summary data for the Fitzroy River Basin in Limpus et al. (2011) indicate that white-throated snapping turtle nests were located a mean distance of 16.6 m from the water’s edge (range 1-86 m) and 2 m above the water level (range 1.2-2.5 m). Hamann et al. (2007) reported nests at a mean of 4.8 m from the water’s edge (range 1-10m) and 2.7 m above the water, generally at the top of steep slopes.

The variations in data may reflect sample sizes or variation in river topography between the sampled sites but suggest overall that this species is able to nest on banks with a variety of substrates and slope angles. Both scattered individual nests and localised aggregations of nests, and both migrations to favoured nest sites and nesting sites close to home pools have been reported for white-throated snapping turtle in the Mary, Burnett and Fitzroy rivers (Hamann et al. 2004, Limpus et al. 2011, Micheli-Campbell et al. 2017).

7.1.2.2.2 Fitzroy River turtle

Less data on breeding habitat requirements is available for the Fitzroy River turtle. Available data is more localised, being largely confined to studies at nesting aggregations on the lower Fitzroy River (Limpus et al. 2011).

The species may lay two or more clutches of eggs (mean clutch size = 18) in spring, with hatching occurring in December-January (Limpus et al. 2011). Limited data on nest site preferences indicate nests are a mean distance of 5.6 m from the water’s edge (range 1-22 m) at a height of 1 m above water level. Available data suggest a preference for females to congregate at favoured nest sites on flood-deposited sand-loam banks, although isolated nests have been recorded (Limpus et al. 2011).

7.1.3 Field habitat assessment

BOOBOOK (2021) assessed potential shelter, foraging and breeding (nesting) habitat for white-throated snapping turtle and Fitzroy River turtle within and upstream of the proposed action area, including sites on the Dawson River and in the waterhole. The survey also characterised any threatening processes present. As the turtles were already known to inhabit the area, trapping surveys, seine netting or night spotlighting were not undertaken.

The habitat survey focused on the potential for habitat loss as a result of inundation from desalinated releases. No assessment was made of water quality parameters or water chemistry, for which pre-existing data is available (e.g., frc environmental 2019b).

7.1.3.1 Drainage feature

Aquatic habitat along the ephemeral drainage feature that carries desalinated water from the pipeline outlet to the waterhole is negligible for the most part (i.e. predominantly terrestrial), except at the lower end near its confluence with the waterhole. However, even at the downstream end of the drainage feature, aquatic habitat elements were limited to minor channel formation, minimal pooling of release water and low diversity and percent cover of aquatic plants.

Due to the ephemeral nature the drainage feature is not considered to have suitable habitat for either white-throated snapping turtle or Fitzroy River turtle and is not discussed further in relation to potential impacts on the two species.

7.1.3.2 Waterhole

7.1.3.2.1 Waterhole turtle habitat

The waterhole can be considered in two parts based on its morphology:

- Upstream (north west) of the confluence with the drainage feature (site WLMP1 of frc environmental (2019a): Appendix A) the waterhole is shallower, typically covered by submerged and emergent macrophyte beds. During the baseline pre-GLNG Project studies (2012-2015) this section of the waterhole often comprised of disconnected shallow pools to dry habitat between rain events (Figure 6-3), and
- Downstream (East) of the confluence with the upstream drainage feature the waterhole is deeper, with macrophyte beds confined to the margins. During the baseline pre-GLNG Project studies (2012-2015) this eastern section of the waterhole appears to have consisted of larger disconnected pools that contained water longer but also dry habitat between rain events.

Historical aerial photography (refer to Section 6.4.4.1) indicates that prior to commencement of GLNG Project desalinated releases, the waterhole was ephemeral highly variable seasonal extent as indicated in Figure 6-3 in 1997 during a dry period and in Figure 6-4 in 2013 during a wet period. The waterhole discharged intermittently to the Dawson River via the watercourse during rainfall events and / or flooding in the Dawson River. Historical imagery shows that the upstream, northern end of the waterhole was historically the most prone to drying in low-rainfall periods, with the monitoring site at upstream end of the Waterhole dry on a number of the baseline surveys while the downstream end held water on all baseline surveys.

The waterhole habitat is monitored under the REMP and the current condition is described as follows (frc environmental 2020):

- Bank stability - moderate with low to moderate bank slope
- Vegetation cover - highly variable and sometimes low, with significant cattle disturbances to the bank
- Bed stability - low to moderate with little scouring or deposition
- Substrate diversity - low, consisting of submerged fine unconsolidated silt and clay
- Physical habitat features - moderate and higher than pre-desalinated release conditions, limited woody debris and aquatic plants, no variation in substrate composition.

The waterhole and watercourse connecting it to the Dawson River is not considered to be critical habitat for the white-throated snapping turtle or the Fitzroy River turtle, because there are not likely suitable nesting banks above the waterhole banks or riffle habitats present (BOOBOOK 2021). One observation of the white-throated snapping turtle in the waterhole was recorded in 2017 (frc environmental 2019a). BOOBOOK's (2021) subsequent study indicated that it is not possible to say whether this observation represented a movement into the waterhole facilitated by the water release or a movement during a flood event, nor can there be any certainty about when the turtle entered the waterhole.

BOOBOOK (2021) further state that whilst individual white-throated snapping turtles may enter the waterhole and possibly stay for prolonged periods, it is unlikely that the species is be abundant in the waterhole due to the lower range of habitats available to be used by the species and based on the absence of observation in GLNG Project REMP data from 2015 to 2022. The GLNG Project REMP data reports many tens of Krefft's river turtles (*Emydura macquarii krefftii)* in the waterhole but only a single observation of the white-throated snapping turtle over the seven-year period.

7.1.3.2.2 Waterhole turtle nesting habitat

Unconsolidated silt banks of the Waterhole could provide nesting habitat for threatened turtles; however, sandy banks along the Dawson River are considered to provide more quality nesting habitat (frc environmental 2019a, BOOBOOK 2021).

7.1.3.3 Dawson River

7.1.3.3.1 Dawson River turtle habitat

The Dawson River within and upstream of the proposed action area has been characterised as having a relatively narrow channel with moderate to steep banks and perennial flow, although flow magnitude has high inter-annual variability, with flood flows recurring every few years (AECOM 2016a, b and Figure 5-10). As noted in Section 5.2.2.3 and Section 6.3.2 the Dawson River has a perennial base flow derived directly from spring discharges and baseflow sourced where the river incises the Precipice Sandstone upstream of the proposed action area.

The Dawson River upstream of the proposed action area comprises a sandy bed with shallow riffles connecting intermittent deeper pools that are generally relatively small. Pools often occur upstream of outcropping boulder rock, with groundwater discharge from the Precipice Sandstone maintaining water levels in these pools. Baseflow contributions to the Dawson River increase within the proposed action area downstream of the Precipice Sandstone baseflow discharge, where pool length, width and depth increase, with some pools being several hundred metres in length. Pools are connected by continuous flow in shallow runs, glides and riffles.

Within the proposed action area pools have maximum depth of 1.0-2.0 m in depth on average and contain low to moderate cover of large woody debris (logs, fallen trees) and often feature undercut banks. Small macrophyte beds (e.g., *Vallisneria sp*., *Potamogeton crispus*) are common where areas of silty sand substrate provides suitable conditions.

The Dawson River bed substrate within the proposed action area is dominated by sand, especially in runs, riffles and glides, with limited presence of rocky substrates other than outcropping rock which confines some pools (compared to upstream of the proposed action area). frc environmental (2019) noted that transient sandy sediments mobilised in flood events were likely to cover cobble substrates, at least temporarily. Deeper pools are likely to have silty to silty sand substrate as flow velocity (and stream power) is lower in pool habitat. Rocky riffles were only rarely identified during the BOOBOOK (2021) survey. Woody debris was moderately common within riffles.

River banks were composed of sand and sandy loam substrates, with bank slope ranging from moderate to steep, and bank height ranging from approximately 1 to >10 m. Both sparsely vegetated sandy banks, and more heavily vegetated banks, occur along the Dawson River within and upstream of the proposed action area. Suitable nesting banks for both Fitzroy River turtle and white-throated snapping turtle occur along the Dawson River within and upstream of the proposed action area, noting that cattle access to some nest sites was observed.

In summary, the Dawson River upstream, within and downstream of the proposed action area provides a continuous length of suitable riverine habitat for both white-throated snapping turtle and Fitzroy River turtle. This habitat was consistent with the definition of critical habitat to the survival of the species given in the National Recovery Plan for white-throated snapping turtle (Commonwealth of Australia 2020); and consistent with the description of Fitzroy River turtle habitat provided by TSSC (2008).

As noted, suitable habitat occurs further downstream from site S4 (the downstream extent of the proposed action area) on the Dawson River, and elsewhere in the Fitzroy Basin. Thus, critical habitat to the survival of these turtle species is not limited to only reaches of the Dawson River within and upstream of the proposed action area.

7.1.3.3.2 Dawson River nesting habitat

The stretch of the Dawson River within and upstream of the proposed action area was found to provide a variety of riverine landforms suitable for the location of nests by both turtle species. Broadly the following landforms are present within the proposed action area that relate to potential turtle habitat:

1) high banks - where the river cuts into steep hillsides or where the edge of the alluvial plain containing the waterhole is located
2) alluvial terrace – extending inwards to the crest of the inner high bank, typically of variable width and typically with loamy to sandy loam soils
3) inner high banks - comprised of stable sandy loam to silty clay loam of varying slope up to 50 degrees and to a height of 6 m to 10 m above the riverbed
4) first bench and sandbanks - generally present, particularly above riffles, at a height of 0.3 m above riverbed level with varied in width from <1 m to several metres, the larger benches forming sandbanks with or without a low grass cover observed to be1.5 m to 2.0 m above water level, and
5) low sandbanks - commonly present within the main channel adjacent to riffle zones, glides and runs at elevations lower than the first bench consisting of transient sediment within the bed of the Dawson River that is highly mobile (Santos 2012, AECOM 2016a, b) that are re-positioned during and after high flow events.

These landforms are presented in Figure 7-3 for a section of the Dawson River upstream of DRR1 and adjacent the alluvial plain containing the waterhole.

Low sandbanks and channel deposits within the main channel are unlikely to be used as nest sites as they would be vulnerable to small rises in water level associated with local rainfall event run-off where rapid water level rises to small rain events inundate the sand banks (refer to Figure 5-14 and Figure 5-15).

The slopes and crests of the inner high banks and higher sandbanks are considered the most likely sites for turtle nest location as indicated in Figure 7-3. Based on reported nest occurrences (Limpus et. al. 2011), a conservative approach would be to assume that the alluvial terraces may also be used by both turtle species as nest sites, even though nesting is more likely to occur closer to the main channel.

Four nests detected during the BOOBOOK (2021) field survey were positioned at heights ranging from 0.6 m to 5 m above the water level observed at the time. Three of the four nests were observed to be predated by native (dingos, goannas) and non-native (fox, cats, pigs etc) species with the remaining nest being intact.

Based on measurements of shell fragments, and the timing of the fresh nest attempt, all but one of these were thought to be white-throated snapping turtle nests. All four turtle nests detected during the BOOBOOK (2021) field survey were located on the slopes or crest of the inner high bank, or on sand to sandy-loam banks below the slope of the high bank (Appendix H- Figure 30).

Some locations within and upstream of the proposed action area (e.g. broad alluvial terraces on accreting banks) may provide areas suitable for more concentrated turtle nesting densities. A more detailed description of the nesting habitat within and upstream of the proposed action area is presented in Appendix H.

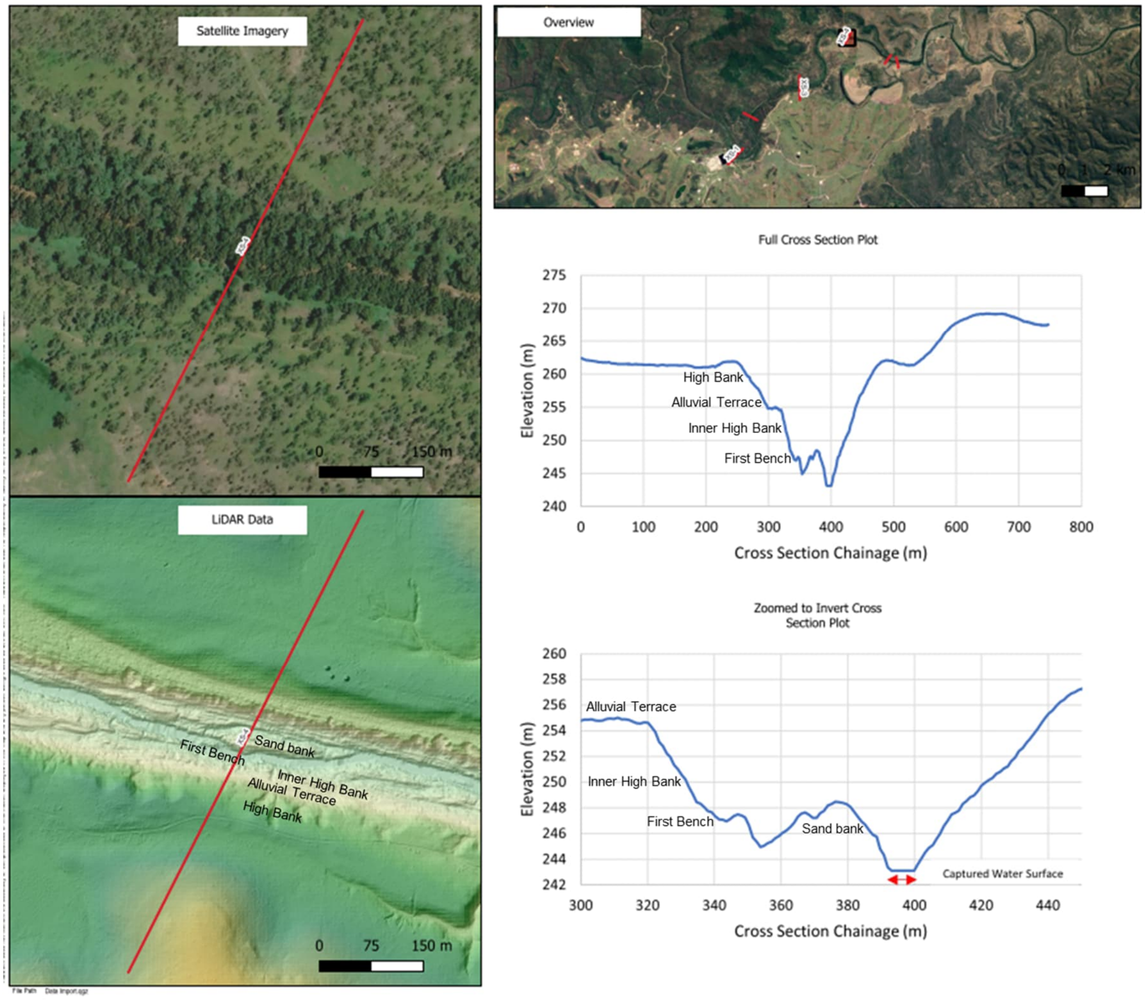

Figure 7-3 Dawson River Channel Landforms and potential turtle nesting habitat

7.2 Impact assessment

The proposed action is the release of up to 18 ML/day of desalinated produced water to the Dawson River via the drainage feature, waterhole and outlet watercourse to the Dawson River. There will be no increase in the existing approved maximum daily release rate (18 ML/day) or total annual volume of 6,570 ML/year. GFD Project water will substitute GLNG Project water, and other water management and beneficial use options such as irrigation will remain in place.

This section assesses the potential impacts of the proposed action to MNES turtles including:

- Influences on hydrology (flow rates, water levels, bank stability)
- Erosion or inundation of nesting habitat, and
- Sediment and contaminant effects to cloacal respiration and foraging behaviour.

Physiological impacts of geogenic and anthropogenic chemicals in produced water together with toxicological assessment is provided in Section 8.1. Assessment of potential impacts within the context National Recovery Plans and Threat Abatement Plans is provided in Section 7.2.5**.**

7.2.1 Habitat impacts

7.2.1.1 Waterhole

The waterhole has a lower range of habitat typically used by both species of MNES turtle compared to the Dawson River. The waterhole, whilst providing habitat that may be utilised by MNES turtles, is not critical habitat for the survival of the species. The waterhole probably functions more as intermittent or opportunistic habitat for turtles based on REMP observation of MNES turtles recorded to date.

Potential impacts from desalinated water releases to the waterhole are not considered to be substantial for either species due to the absence of critical habitat for the survival of the species.

7.2.1.2 Dawson River

Nesting

Measured water depth increase during desalinated water releases at the Yebna Crossing S4 location indicates an increase of no more than 0.05 m under baseflow conditions and both 13.5 ML/day and 18 ML/day desalinated water discharge rates as indicated in Figure 5-14 and Figure 5-15. The increase in water depth following the start of desalinated water release is gradual and occurs over several days, compared to same day increases in water depth following rainfall within the catchment as observable in Figure 5-14. Under base flow conditions the change in water velocity in the Dawson River during desalinated water release events is calculated to be 0.07 m/s (0.28 m/s to 0.35 m/s), decreasing to a 0.01 m/s increase under flood conditions.

The measured increase in water depth under both 13.5 ML/day and 18 ML/day desalinated water release rates are below the first bench in the banks of the Dawson River downstream of the waterhole discharge location. Under higher flow conditions during wet season conditions water depth changes are indiscernible in measured REMP data. The measured water depth increase is contained within the bed and banks below the first bench and below the height of observed nests and suitable nest habitat typically located at heights greater than 1.5 m above baseflow levels.

As indicated in Section 7.1.2.2 sandy banks provide turtle nesting habitat, and cobbles in riffle zones provide foraging substrate. The white throated snapping turtle nests between May and December and the Fitzroy River turtle between September and November, both during the dry season dominated by baseflow conditions (Figure 3-4). Nests of the white-throated snapping turtle are stated to be typically 2 m above baseflow water levels and the Fitzroy River turtle 1 m above water level as indicated as discussed Section 7.1.2.2.

The white throated snapping turtle nests between May and December and the Fitzroy River turtle between September and November, both during the dry season dominated by baseflow conditions (Figure 3-4).

The BOOBOOK (2012) survey recorded turtle nests at 0.6 m to 5 m heights within the Dawson River. This is above the measured 0.5 m water depth increase under baseflow conditions. Turtle nests placed on the slope or crest of lower banks remain above the measured and calculated water level within the proposed action area and are not considered to be impacted by the proposed action.

Habitat

During wet season high flow conditions, no discernible increases in flow depth or discharge are evident in gauged data (Figure 5-1) or calculated levels (Section 5.2.2.3). Therefore, desalinated water release impacts to turtle habitat under high flow wet season (non-nesting) conditions are not discernible above the naturally occurring condition.

Based on pre-2015 baseline assessments covering a range of flow levels from low flow to flood flow, frc environmental (2019b) concluded that:

- natural bank stability was moderate, with some unstable and eroding sections.
- natural bed stability was low, with significant scouring and deposition of sand following very high flow events.

The REMP data indicates that the riverbank environment is reasonably resilient to flood-induced erosion events, with stream bank stability monitoring indicating no significant change from baseline conditions, as recorded in REMP reports in Appendix F, outside that expected under the dynamic nature of the Dawson River with west season flood events of up to 9 m water depth.

Large (flood) flow events often cause significant geomorphic changes to in-stream and adjacent low and high bank sediments via scour and deposition. Generally, such changes are natural and important for habitat rejuvenation, but in the context of threatened turtle species may present a risk if sandy banks (nest sites) are scoured and cobbly riffles (foraging habitat) are smother by deposited sediment during natural flood events in the nesting season.

The overall influence of the proposed action on geomorphic processes that are important for turtles nesting bank formation and general habitat is negligible.

7.2.2 Water quality impacts

7.2.2.1 Waterhole

As stated in Section 7.1.3.1 the waterhole is not considered to provide critical habitat for the survival of white-throated snapping turtle or the Fitzroy River turtle but may be used by the species. Water quality impacts assessed in Section 5.3, incorporating REMP monitoring data, did not identify significant or unacceptable water quality impacts to the waterhole that would reduce water quality to levels unsuitable for turtles. Turtle sensitivity to chemicals, both natural/geogenic[27] and man-made from drilling, fracturing or water treatment are discussed in Section 8.1 and reviewed as part of the chemical risk assessment in Section 8.3.

7.2.2.2 Dawson River

Dissolved oxygen

REMP DO data for DRR1 (upstream of the release) and DRMP1 (downstream of the release) is summarised in Appendix E-2 and Table 7-1. Median DO concentrations at DRR1 (6.3 mg/L) and DRMP1 (7.1 mg/L) are within the WQO. The minimum and 20th percentile are below the WQO in both DRR1 and DRMP1 reflecting the natural variability in the Dawson River.

The Fitzroy River turtle has been said to be reliant on "well-oxygenated[28]" water to allow foraging and resting in fast-running water (Limpus et al. 2011), though this view is increasingly corrected based on observations of both MNES species being observed waters with lower DO conditions such as weirs and pools. White-throated snapping turtle obtain around 74% of its oxygen requirement from water (FitzGibbon 1998, cited in Limpus et al. 2011). Mathie and Franklin (2006) demonstrated experimentally that smaller white-throated snapping turtles depended on cloacal respiration to provide sufficient oxygen to support prolonged dives, which may allow avoidance of predators. Thus, both white-throated snapping turtle and Fitzroy River turtle can be characterised as being dependent on "well-oxygenated" water.

Whilst REMP monitoring data within the Dawson River indicate that DO has a wide range (3.6 mg/L to 11.6 mg/L), median DO values are within the WQO and overall conditions are considered suitable for maintenance of aquatic communities. This is supported by the sighting of both species of turtles (together with other turtle species) in the Dawson River over the wide range of DO and flow conditions together with an assemblage of up to fourteen species of native fishes (frc environmental 2016).

The lower frequency of MNES turtle observations in the Dawson River downstream of the release location may be a limitation of sampling locations and survey effort within those reaches of the proposed action area rather than actual lower populations of the species.

Based on the limited observed difference in DO between upstream DRR1 and downstream DRMP1, water quality and habitat do not appear to be a limiting factor between upstream reaches and downstream reaches within the proposed action area.

[27] Geogenic chemicals are naturally occurring within soil and rock
[28] Current literature does not appear to define "well-oxygenated".

Table 7-1 Summary of dissolved oxygen and total suspended solids data from 2015 to 2022

Quality Characteristic	Dissolved Oxygen		Total Suspended Solids	
Units	mg/L		mg/L	
Location	DRR1 (Upstream)	DRMP1 (Downstream)	DRR1 (Upstream)	DRMP1 (Downstream)
No. Samples/Readings	25	58	26	25
Minimum	3.6	3.4	6.0	6.0
20th percentile	5.2	6.2	10.0	10.0
Median	6.3	7.1	15.0	15.0
80th percentile	7.1	8.9	48.0	49.0
Maximum	7.8	11.6	711.0	174.0
WQO	6.4 – 16.1		No WQO	

Notes
No WQO = No Water Quality Objective
Data Source – 2015 to 2022 REMP monitoring data as summarised in **Appendix E**

Suspended solids

Schaffer et al. (2015) reported that elevated suspended solids concentrations adversely affected dive times in Irwins turtle (*Elseya irwini*), even under conditions of high dissolved oxygen levels. This was attributed to decreased efficiency in cloacal respiration. Sediment loads are likely to similarly reduce dive times, and thus foraging efficiency, in white-throated snapping turtle and Fitzroy River turtle.

AECOM (2016a) noted that the Dawson River within and upstream of the proposed action area can carry very high sediment loads during high flow flood events. Fine sediments are generally lost downstream via entrainment but sand substrate re-establishes with base-flow contributions.

Water quality and sediment quality REMP data discussed in Section 5.3 has not identified a significant impact to water quality under both 18 ML/day and 13.5 ML/day release rates. Table 7-1 indicates REMP monitoring data indicating median TSS of 12.0 mg/L for both DRR1 and DRMP1 and a range of 5.0 mg/L to 711 mg/L across both locations. REMP data indicates low TSS under the majority of conditions as reflected by the median concentration in the upstream and downstream reaches of the Dawson River. REMP data also indicates high TSS at times of higher flow as suggested by maximum concentrations.

At the time of the BOOBOOK (2021) field survey, the Dawson River was in low flow condition within and upstream of the proposed action area; thus, water clarity was high. No appreciable difference in turbidity was apparent between locations upstream and downstream of the waterhole discharge point. BOOBOOK (2021) concluded it was unlikely that turtles' cloacal respiration efficiency was affected by the levels of suspended solids within the Dawson River at the time of survey, noting with active desalinated water release via the waterhole.

7.2.3 Cumulative impact assessment

Other known petroleum/gas and mining releases to Dawson River are situated a considerable distance downstream and most are also temporary in nature, occurring during flow events (AECOM 2021 (Appendix A, Section 11.0).

There are no known existing or known potential future projects (e.g., releases to surface water) located upstream of the proposed action.

Primary impacts to white-throated snapping turtle and Fitzroy River turtle are from nest predation by native (dingos, goannas) and non-native (fox, cats, pigs etc) species (BOOBOOK, 2021). Evidence of nest disturbance and predation was observed by BOOBOOK (2021) (Appendix H). Predation is considered to be the most significant threat to the white-throated snapping turtle and Fitzroy River turtle in the proposed action area (BOOBOOK, 2021), and throughout the entire distribution of the species.

The assessment has not identified significant impacts to groundwater resources, surface water resources (flow and quality), direct habitat disturbance or indirect impact to physiological requirements of the white-throated snapping turtle or Fitzroy River Turtle. As such the proposed action does not contribute to nest predation by native and non-native species that are outside of Santos' control (which is a pre-existing threat). Threats associated with predation are discussed further in the following section.

7.2.4 Threat abatement and recovery planning

The impact assessment for the listed threatened species have been considered in the context of the national threat abatement, conservation and recovery plans:

- White-throated snapping turtle:
  - National Recovery Plan for the White-throated Snapping Turtle (*Elseya albagula*) (2020).
  - Approved Conservation Advice for *Elseya albagula* (White-throated Snapping Turtle) (2014).
- Fitzroy River turtle:
  - Approved Conservation Advice for Fitzroy River Turtle (*Rheodytes leukops*) (2008).
  - Threat Abatement Plan for predation, habitat degradation, competition and disease transmission by feral pigs (Sus scrofa) (2017).
  - Threat Abatement Plan for predation by the European Red Fox (2008).

Known threats to the two species are similar (TSSC 2008, 2014). For both species, the most significant identified threat is a near-total failure of recruitment of juveniles into their population, which is now composed almost entirely of adults, resulting from nest predation. Even though nesting is still commonly occurring, there is a loss of almost all eggs as a result of predation or trampling by cattle of nests (Limpus et al. 2011; TSSC 2008, 2014).

Predators include both native species (goannas, dingo) and non-native feral species (pig, fox, wild dog, cat) (Limpus et al. 2011, DEWHA 2008, Commonwealth of Australia 2017). Trampling of nests by livestock, principally cattle, also results in the loss of eggs. Although other threatening processes are known, the failure to recruit juveniles into the population is considered to be the highest-priority management issue for the two species (Limpus et al. 2011).

The construction of dams and weirs impacts on both species through several mechanisms including obstruction of migration pathways within rivers; fatalities associated with over-topping of dam walls, water releases and drowning in trash screens; flooding of traditional breeding habitat; reduction or prevention of replenishment of sand banks used for nesting; and loss of riparian vegetation that may provide food resources (fallen fruit) (TSSC 2008, 2014).

Reductions in water quality due to pollution and siltation arising from adjacent land uses (agriculture, mining) are also an implicated population threats. Increased sedimentation has been reported to reduce the efficiency of cloacal respiration in Irwins turtle (*Elseya irwini*), a species closely related to the white-throated snapping turtle (Schaffer et al. 2015). Aquatic macrophyte growth is also reduced or prevented under such conditions, particularly when suspended sediments loads are persistent for extended periods.

Both turtle species, but particularly the white-throated snapping turtle are known to be occasionally killed by fishing activities e.g., drowned in traps, killed when captured on fishing lines.

The overall goal of the species recovery plans is to achieve a wild population that has a high likelihood of persistence in nature, and to put in place long-term management arrangements that ensure a healthy population structure and healthy habitat for the species. To achieve this goal a range of strategies are described, including:

- Substantially improve the recruitment of hatchlings into the population.
- Reduce the incidence of adult mortality and injury.
- Maintain and/or improve stream flow and habitat quality throughout the species' distribution.
- Maintain and/or improve the connectivity within populations throughout each catchment.

- Increase public awareness and participation in conservation of the species and its habitat.

The most applicable conservation objectives to the proposed action are identified as:

- Modify water infrastructure design and/or operation to minimise mortality of adult turtles during flood events and water releases and ensure that the design of any subsequent infrastructure also minimises such mortality.
- Ensure that water planning includes allocation for flows that maintain water quality that allows cloacal respiration, particularly during low flow periods (TSSC 2008, 2014).

As described in Section 2.3, no increase to currently authorised release rates, volumes, frequencies, or changes to water quality from existing State EA is being sought under this referral. The GFD Project water will form a component of the maximum volume of produced water already authorised to be released.

As such, the proposed action will not increase the principal threat to the species (nest predation and trampling of nests) and is therefore unlikely to result in a contravention of the national threat abatement, conservation and recovery plans. Potential impacts to habitat and water quality are discussed below.

7.2.5 Significant impact assessment

Potential for Significant Impact on MNES within the proposed action area due to the release of produced desalinated water to the Dawson River were assessed using the EPBC criteria for Significant Impacts on MNES (DoE 2013). The assessment criteria are applicable to Critically Endangered and Vulnerable fauna species.

As per Significant Impact Guideline 1.1 (DAWE 2013), an action is likely to have a significant impact on a critically endangered species such as the white-throated snapping turtle and endangered species such as the Fitzroy River turtle if there is a real chance or possibility that it will:

- *lead to a long-term decrease in the size of a population*
- *reduce the area of occupancy of the species*
- *fragment an existing population into two or more populations*
- *adversely affect habitat critical to the survival of a species*
- *disrupt the breeding cycle of a population*
- *modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline*
- *result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat*
- *introduce disease that may cause the species to decline, or*
- *interfere with the recovery of the species.*

Table 7-2 and Table 7-3 presents the assessment of the proposed action against the above significant impact criteria for the white-throated snapping turtle and Fitzroy River turtle. No Significant Impact was identified to either species associated with the proposed action.

Table 7-2 Assessment of potential significant impacts for the white-throated snapping turtle

Significant Impact Criteria	Impact	Assessment
Lead to a long-term decrease in the size of a population (including declines due to loss or modification of habitat).	Unlikely	The Dawson River is subject to a highly variable flow regime, including sometimes extreme flow events, yet it provides suitable aquatic (foraging and sheltering) and terrestrial (nesting) habitat. Minimal or negligible changes to water quality and flows, and no change to river geomorphology of the Dawson River are expected as a result of water releases into this environment. There is low risk of impact on the Dawson River (and waterhole as opportunistic habitat), including its suitability as habitat for *E. albagula*.
Reduce the Area of Occupancy (AoO), or the Extent of Occurrence (EoO) of the species.	Unlikely	The species occurs throughout the Dawson River, including upstream, within and downstream of the proposed action area, and more widely throughout the Fitzroy River, Burnett and Mary River basins. No changes to the riverine environment are expected as a result of the proposed action. Therefore, no reduction in AoO or EoO is likely to occur.
Fragment an existing population into two or more populations; or result in genetically distinct populations forming.	Unlikely	Perennial flows are present within the proposed action area but cease further upstream at the junction of the Dawson River with Hutton Creek. Above this the species is only recorded in relatively few permanent, spring-fed pools (Limpus et al. 2011, BOOBOOK unpubl. data). The Action will not impact the connectivity of flows upstream or downstream of the release point, nor will it form a barrier to aquatic fauna passage. No changes are expected in the species' population within the proposed action area. The proposed action will not fragment the population of the species.
Adversely affect habitat critical to the survival of a species (including disruption to breeding, feeding, nesting, migration or resting sites).	Unlikely	The Dawson River is subject to a highly variable flow regime, including periodic extreme flow events, yet it provides suitable aquatic (foraging and sheltering) and terrestrial (nesting) habitat. Minimal or negligible changes to water quality and flows, and no change to river geomorphology, of the Dawson River are expected as a result of desalinated water releases into this environment. Minimal changes in low flow water heights and velocity at the proposed maximum release volumes will not impact on the suitability of the proposed action area as foraging and shelter habitat (e.g., no alteration of abundance of aquatic macrophytes or riparian vegetation) or breeding habitat (e.g., no increase in frequency or duration of inundation of nesting banks). No significant direct or indirect impact to, or unacceptable change of, habitat for *E. albagula* is likely to occur.
Result in invasive species that are harmful to a threatened species becoming established in the threatened species' habitat.	Unlikely	Minimal or negligible changes to water quality and flows, and no change to river geomorphology, of the Dawson River are expected as a result of water releases into this environment. As a result, no changes that may favour either aquatic or terrestrial invasive species are likely to occur within the proposed action area. Note that several plant and animal species known or potentially adversely impacting on the species are present already, including feral pigs and horses, dingoes, livestock (cattle); two species of non- native fish; and non-native pasture grasses that may dominate terrestrial nesting areas in some places. No material change in abundance or distribution of these species is expected as a result of the proposed action. Therefore, no exacerbation of any pre-existing impact is expected.
Introduce disease that may cause the population to decline.	Unlikely	The proposed action is unlikely to introduce a disease that will cause the population to decline. The desalinated water releases are unlikely to produce an ecotoxic impact on either the turtle or on other species within the aquatic environment. It is unlikely to be a source of pathogens. No external inputs likely to transmit disease are involved in the proposed action.

Significant Impact Criteria	Impact	Assessment
		Minimal or negligible changes in flows are unlikely to produce change affecting the incidence or severity of any disease already present (none are known).
Interfere with the recovery of the species.	Unlikely	Minimal or negligible changes to water quality and flows, and no change to river geomorphology of the Dawson River, are expected as a result of water releases into this environment. Thus, changes in the aquatic and terrestrial environment are expected to be negligible or non-existent. The proposed action is unlikely to impact the extent and quality of foraging, shelter and nesting habitat for the species. It will not affect the extent of the species, nor interfere with movement by the species within the proposed action area or movement of the species upstream or downstream from the proposed action area. It will not allow the introduction of, or exacerbate the existing impact of, invasive species or diseases. The recovery of the species will not be adversely affected by the Action.

Significant impact conclusion

The proposed action is **unlikely** to create a Significant Impact on the population of white-throated snapping turtle.

- Based on empirical data from the current REMP program and by default the proposed action the Proposed Action will not lead to a long-term decrease in the size, reduction in the area of occupancy, fragment existing populations, adversely affect habitat critical to the survival, disrupt the breeding cycle, modify, destroy, remove, isolate or decrease the availability or quality of habitat that would result in a decline in numbers, to the extent that the species is likely to decline, result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat, introduce disease that may cause the species to decline, or interfere with the recovery of the white throated snapping turtle.

Table 7-3 Assessment of potential significant impacts for the Fitzroy River turtle

Significant Impact Criteria	Impact	Assessment
Lead to a long-term decrease in the size of a population (including declines due to loss or modification of habitat).	Unlikely	The Dawson River is subject to a highly variable flow regime, including sometimes extreme flow events, yet it provides suitable aquatic (foraging and sheltering) and terrestrial (nesting) habitat. Minimal or negligible changes to water quality and flows, and no change to river geomorphology of the Dawson River are expected as a result of water releases into this environment, based on pre- and post-release studies. There is low risk of impact on the Dawson River (and waterhole as opportunistic habitat), including its suitability as habitat for *R. leukops*.
Reduce the Area of Occupancy (AoO), or the Extent of Occurrence (EoO) of the species.	Unlikely	Recent records (frc environmental 2019a) of this species within the proposed action area represent the furthest upstream records in the Dawson River. Though survey effort has been limited, the lack of records between the proposed action area and Theodore (a distance of approximately 260 km downstream from the proposed action area) suggests that the species is rare along much of the intervening river. The upstream limit is possibly the Hutton Creek junction with the Dawson River, because flow in the Dawson River upstream of this point is not perennial. Thus, the species is likely at its western range limit a short distance upstream from proposed action area. No changes to the riverine environment are expected as a result of the proposed action and no reduction in AoO or EoO is likely to occur.
Fragment an existing population into two or more populations; or result in genetically distinct populations forming.	Unlikely	The species is near the distributional limit in the Dawson River a short distance upstream of the proposed action area. The Action will not impact the connectivity of flows upstream or downstream of the release point, nor will it form a barrier to aquatic fauna passage. No changes are expected in the species' population within or beyond the proposed action area. The proposed action will not fragment the population of the species.
Adversely affect habitat critical to the survival of a species (including disruption to breeding, feeding, nesting, migration or resting sites).	Unlikely	The Dawson River is subject to a highly variable flow regime, including periodic extreme flow events, yet it provides suitable aquatic (foraging and sheltering) and terrestrial (nesting) habitat. Minimal or negligible changes to water quality and flows, and no change to river geomorphology, of the Dawson River are expected as a result of desalinated water releases into this environment. There is low risk of impact on the aquatic ecology of the Dawson River, including its suitability as habitat for *R. leukops*. Minimal changes in low flow water heights and velocity will not impact the suitability of the proposed action area as foraging and shelter habitat (e.g., no alteration of abundance of submerged woody debris). Breeding by the species within the proposed action area has not been confirmed to date, but no significant impact to nesting habitat (e.g., no increase in frequency or duration of inundation of potential nesting banks) is expected to occur.
Result in invasive species that are harmful to a threatened species becoming established in the threatened species' habitat.	Unlikely	Minimal or negligible changes to water quality and flows, and no change to river geomorphology, of the Dawson River are expected as a result of desalinated water releases into this environment. As a result, no changes that may favour either aquatic or terrestrial invasive species are likely to occur within the proposed action area. Note that several plant and animal species known or potentially adversely impacting the species are present already, including feral pigs and horses, dingoes, livestock (cattle); two species of non- native fish; and non-native pasture grasses that may dominate terrestrial areas in some places. No change in abundance or distribution of these species is expected as a result of the proposed action. Therefore, no exacerbation of any pre-existing impact is expected.

Significant Impact Criteria	Impact	Assessment
Introduce disease that may cause the population to decline.	Unlikely	The proposed action is unlikely to introduce a disease that will cause the population to decline. The desalinated water release is unlikely to produce an ecotoxic impact on either the turtle or on other species within the aquatic environment. The desalinated water releases are unlikely to be a source of pathogens. No external inputs likely to transmit disease are involved in the proposed action. Minimal or negligible impacts on flows and hydrology are unlikely to produce change affecting the incidence or severity of any disease already present (none are known).
Interfere with the recovery of the species.	Unlikely	Minimal or negligible changes to water quality and flows, and no change to river geomorphology, of the Dawson River are expected as a result of desalinated water releases into this environment. Thus, changes in the aquatic and terrestrial environment are expected to be negligible or non-existent. The proposed action is unlikely to impact on the extent and quality of foraging, shelter and nesting habitat for the species. It will not affect the extent of the species, nor interfere with movement by the species within the proposed action area or movement of the species upstream or downstream of the proposed action area. It will not allow the introduction of, or exacerbate the existing impact of, invasive species or diseases. The recovery of the species will not be adversely affected by the proposed action.

Significant impact conclusion

The proposed action is **unlikely** to create a Significant Impact on the population of Fitzroy River turtle

- Based on empirical data from the current REMP program and by default the proposed action the Proposed Action will not lead to a long-term decrease in the size, reduction in the area of occupancy, fragment existing populations, adversely affect habitat critical to the survival, disrupt the breeding cycle, modify, destroy, remove, isolate or decrease the availability or quality of habitat that would result in a decline in numbers, to the extent that the species is likely to decline, result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat, introduce disease that may cause the species to decline, or interfere with the recovery of the Fitzroy River turtle.

7.3 Proposed avoidance, mitigation and management

As no significant impact has been identified, no additional mitigation measures are considered to be required with respect to the proposed releases to the receiving environment. The release design (i.e., release to tributary and waterhole, prior to discharging into the Dawson River), and maintaining appropriate water quality as prescribed by the conditions of the State EA, adequately mitigate the risk of impacts on the turtle species.

Ongoing monitoring of water quality, flow characteristics and abiotic and biotic parameters of riverine ecosystem health will be continued within the scope of the REMP. The REMP (Appendix J) has been updated to add visual observation/counting at each location via snorkelling as well as fyke nets and cathedral traps currently used. This will provide a more robust data collection of turtle species within monitoring locations. Further details on the REMP are provided in Section 9.0.

BOOBOOK (2021) indicate that the most significant threat identified for both turtle species is the negligible recruitment into the population due to predation, and trampling by cattle, of eggs, which is unrelated to the proposed action. Though both species would have co-evolved with native nest predators, novel predators such as the introduced pig and red fox have elevated losses to an unsustainable level. Additionally, access to riverbanks by livestock (especially cattle) results in trampling of shallow nests.

Field survey confirmed that pigs were common and that they dug up extensive areas of riverbank within the proposed action area. Three predated nests, identified by broken eggshells, were detected but the predator involved could not be determined. Cattle and feral horses access the banks, with trampling, track formation and bank erosion commonly observed.

There is potential to install exclusion fences and/or conduct a program of coordinated trapping, poison baiting, or nesting habitat protection, to mitigate the impact of feral pigs, feral horses and cattle within the area. However, it would necessarily require the cooperation of relevant landholders to be effective.

8.0 Chemical risk assessment

Chapter summary

Cloacal breathing turtles are considered to be sensitive to chemicals dissolved in water, similar to fish, with adsorption through cloacal villi and gill filaments respectively. Evidence indicates that water column exposure to chemicals via cloacal respiration is the most significant pathway for turtle chemical exposure. The chemical risk assessment has considered potential risk to turtles through their life cycle stages including egg, juvenile and adult stages.

Freshwater turtles lay their eggs on higher river banks, typically greater than 1.5 m above baseflow levels, within the Dawson River. Given that nests are not submerged in river water or saturated sediments the risk of exposure to chemicals from desalinated water during embryo development within the egg is considered to be negligible.

For juvenile and adult life stages existing ANZG (2018) aquatic water quality guidelines for chemicals are expected to be protective of turtle populations because these water quality guidelines are designed to protect ecosystems comprising water-respiring animals including fish and invertebrates that pass water over gills etc/villi for respiration.

The ANZG (2018) state that ecotoxicity results from a range of standardised test species will be representative of ecotoxicity experienced by all wildlife within an ecosystem i.e., ecotoxicity data for freshwater algae, invertebrates and fish will be representative of ecotoxicity to freshwater turtles.

The desalinated water quality is required to meet the drinking water environmental value and apart from ammonia, desalinated water meets required State EA CL. Ammonia concentrations decrease in the waterhole to levels lower than desalinated water.

A chemical risk assessment framework (CRAF) has been developed in accordance with guidance issued by DCCEEW. In accordance with the CRAF an evaluation of all chemicals proposed for use was conducted, including those used in drilling and completions, hydraulic fracturing and water treatment.

The majority of chemicals were classified as Tier 1 chemicals (146), with 37 chemicals (Tier 2 and Tier 3 chemicals) assessed in a more detailed manner. The chemical risk assessments found that none of the Tier 2 and Tier 3 chemicals had exposure point concentrations (EPCs) for treated produced water (desalinated water) greater than Predicted No-Effects Concentrations (PNECs). In other words, none of the predicted concentrations in the receiving environment were above a concentration that is expected to be ecologically toxic.

The chemical risk assessments indicated no significant risks and effects of chemicals to MNES or non-MNES receptors.

The 2021 DAWE RFI requested an assessment of the potential for adverse impacts to the listed threatened species (freshwater MNES turtles *E. albagula* and *R. leukops*) and water resources from exposure to process and geogenic chemicals present in desalinated water released to the Dawson River. This assessment was conducted by performing the following scope of work:

- desktop literature review to identify if a particular lifecycle stage of the turtle is more sensitive to chemical exposure (refer to Section 8.1)
- desktop literature review regarding the relevance of available ecotoxicity data for turtles in Australia, and globally, and consideration of how ecotoxicity data from other common test species could be applicable to turtles (refer to Section 8.2).
- review of chemical risk assessment documentation developed to evaluate risks from chemicals proposed for use within the Santos GFD Project potentially present in desalinated waters and for geogenic chemicals to aquatic MNES turtles and water resources (refer to Section 8.3).
- preparation of a Dawson River conceptual site model (Figure 3-2) and ecohydrological conceptual model (Figure 3-4) specific for freshwater turtles illustrating the source-pathway-receptor linkages between process and geogenic chemicals and the MNES turtles (refer to Section 3.2)

The above scope of work was updated following receipt of DCCEEW and IESC comments in August 2022.

8.1 Turtle ecotoxicity

This section presents the results of the literature review that was undertaken to characterise the freshwater MNES turtle's (White-throated snapping turtle and Fitzroy River turtle) lifecycle sensitivity to chemical exposure and relevant available Australian and international ecotoxicity data for turtle species.

The literature review identified that there are limited published ecotoxicological studies available for *E. albagula* and *R. leukops* or ecotoxicity data for other turtle species that have been exposed to chemicals potentially present in the desalinated waters to be released to the Dawson River. Therefore, ecotoxicity studies for common freshwater turtle species found in Australia and internationally that were exposed to other chemicals not found in desalinated water (i.e., organochlorine pesticides, polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs)) were included in the literature review for comparative purposes.

8.1.1 Breeding cycle

The white-throated snapping turtle is slow growing, with adults growing at less than 0.5 cm per year (Hamann et al., 2007). The species can take 15-20 years to reach sexual maturity (Limpus, 2008) at a relatively large size, with minimum sizes at maturity being 33.1 cm for females and 19.2 cm for males (Hamann et al., 2007). Breeding occurs during the dry season. A single clutch of eggs is laid per annual breeding season, with an average of 14 eggs per clutch (Hamann et al., 2007; Limpus, 2008; Limpus et al., 2011b). Eggs are laid in nests situated along riverbanks in riparian vegetation primarily in the sand and loam alluvial deposits from previous flooding events. The eggs employ embryonic diapause which continues after the eggs are laid, with resulting delays in embryonic development so that hatching occurs during the wet season (in spring and summer) when conditions are optimal for food resources and dispersal (Hamann et al., 2007).

The Fitzroy River turtle reaches sexual maturity at around 15-20 years old (Limpus et al., 2011a). The breeding cycle for an adult female is approximately one year and each female can lay two or more egg clutches per year during spring (September-November). The incubation period is dependent upon environmental conditions with hatching generally occurring during summer (November-March) (Limpus et al., 2011a; Limpus et al., 2011b). Eggs incubated at 30°C hatch in 47 days (Cann, 1998). Eggs incubated in natural nests have been recorded to take up to 90 days to hatch (Legler, 1985).

8.1.2 Sensitivity to chemicals

Limpus et al. (2011a) suggested that cloacal-respiring[29] turtles (refer to Section 7.1.2.1) were more likely to take up dissolved chemical contaminants than species with more reliance on lung respiration. Jeffree and Jones (1992) showed that cloacal radiocalcium uptake in three Australian turtle species (*Elseya dentata*, *Chelodina longicollis* and *Emydura signata*) was at least four times more important than uptake via the buccopharyngeal[30] route (respiration through the lining of the mouth**)**. They attributed this to the structure of the cloaca, with its development of epithelial folds and abundant villi. The high degree of development of respiratory structures in the cloaca of *E. albagula* and *R. leukops* would suggest the potential for an efficient uptake of dissolved contaminants.

Freshwater turtles have attracted attention as potential bio-indicator or sentinel species for aquatic chemical contaminants due to their trophic level, longevity and site fidelity (e.g., Browne, 2009; Adams et al., 2016).

Internationally, and particularly in the United States where freshwater turtles are widely distributed, numerous studies have shown bioaccumulation of contaminants in turtle tissue such as radionuclides, heavy metals, organochlorine pesticides, PCBs and PAHs entering the aquatic environment via industrial, mining and agricultural land use (USGS, undated; Yu et al., 2011; Zychowski, 2017).

The United States study sites are typically biased towards areas contaminated with environmental pollutants, for example the Paducah Gaseous Diffusion Plant (PGDP) in Kentucky was the investigation site in the Yu et al., (2011) study where groundwater and sediment in the ponds near the PGDP were contaminated with heavy metals due to the leaching and dissolution of contaminants from the solid

[29] Through cloacal respiration, turtles can extract dissolved oxygen from the water by moving the water over their body surfaces covered in blood vessels.
[30] Buccopharyngeal respiration is the mode of respiration through the mouth and pharynx (buccopharyngeal cavity).

waste management units. Lead and copper concentrations in the sediment ranged from 3.345 to 4.856 mg/kg and 1.994 to 4.802 mg/kg, respectively. These heavy metal concentrations are considerably higher than those detected in the proposed action area and are not considered representative of the concentrations that have been previously observed in the desalinated water released to the Dawson River via the drainage feature, waterhole watercourse system (refer to Appendix E-2).

The Big River in the Old Lead Belt of Missouri, a United States Environmental Protection Agency (USEPA) superfund site contaminated with lead mine tailings was selected as the investigation area in the study conducted by Overmann (1995) to assess if Snapping Turtles were appropriate biomonitors of lead contamination. Lead concentrations in sediment samples collected within the Big River watershed ranged from 35 mg/kg to 35,700 mg/kg. Two collection sites were upstream of the tailings pile and one site was downstream. The downstream site tended to have higher lead values than upstream sites for tissues sampled, and significantly higher values for liver, blood, carapace, and bones. The site outside the Old Lead Belt had the lowest concentrations for each tissue.

Mean lead concentrations (µg/g wet weight) for the three study locations ranged from: 0.126-0.201 muscle, 0.166-0.292 brain, 0.177-0.490 liver, 0.280-2.514 blood, 0.977-33.013 carapace, and 1.015-114.563 bone. The study concluded that the lead levels in the Big River did not appear to be adversely affecting resident Common Snapping Turtle (*Chelydra serpentina*). This demonstrated that *C. serpentina* was a useful species for biomonitoring of lead contaminated aquatic environments.

Reported lead concentrations in the Big River are significantly higher than those previously observed in the proposed action area where it is not detected in the Dawson River or desalinated water above the lead LoR of 0.001 mg/L (Appendix E-2). Therefore, assuming the toxicity response of the MNES turtles to lead is similar to *C. serpentina*, it is unlikely that the MNES turtles will be adversely affected by desalinated water releases to the Dawson River where lead is consistently less than 0.001 mg/L.

A summary of responses to contaminants by the widespread and well-studied *C. serpentina* in the United States (USGS, undated) indicated the occurrence of abnormal development and deformity of embryos and poor hatching rates due to exposure to PCBs and PAHs; and depression of heme-building enzyme activity due to high lead levels. It is noted that no PAHs (sum of PAH = <0.005 µg/L) have been detected in desalinated water released to the Dawson River. PCBs are not a contaminant of concern for CSG produced water or desalinated water.

Turtle eggs are also used as biomonitors of environmental contamination because contaminants can be transferred to eggs from female turtles (e.g., Hillestad et al. 1974; Stoneburner et al., 1980). Turtle eggs have been used to evaluate contamination of heavy metals (Tryfonas et al., 2006), PAHs (Holliday et al., 2008), PCBs (Dabrowska et al., 2006; Kelly et al., 2008), organochlorine pesticides and dioxins/furans (de Solla and Fernie, 2004; Henny et al., 2003).

Experimental exposure of snapping turtle eggs collected from the John Heinz National Wildlife Refuge in the USA to PAHs correlated with poor hatching success, the appearance of deformities and decreased survival (Van Meter et al., 2006). Eisenreich et al. (2009) reported that juvenile common snapping turtles exposed to maternally derived PCBs had higher mortality rates than turtles from reference sites at approximately eight months after hatching. Considering that the majority of these studies report abnormal development, deformity of embryos, poor hatching rate and mortalities in juvenile turtles, it is considered that hatchlings and small juveniles are the most sensitive to chemical contaminants.

However, it is noted that other than metals and metalloids (at low concentrations – refer to Section 5.1 and Appendix E-2), the chemicals mentioned in the studies (PAHs, PCBs, radionuclides, organochlorine pesticides and dioxins/furans) are not found in desalinated water released under the proposed action.

No toxicological studies have been found regarding turtle exposure to the chemicals in the desalinated water as listed in Table 8-3 and Table 8-4. Some studies have linked the presence (or elevated levels) of contaminants to various pathologies in affected turtles such as fibropapillomatosis, a disease in sea turtles which has been associated with metal contamination (Bruno et al., 2021). However, a definitive cause-and-effect relationship is often difficult to define for the following reasons:

- variation in responses between turtle species

- variation in toxicity of chemicals within the same class
- the complexity of the physical and chemical environment in which some studies were performed, and
- the lack of controlled (e.g., experimental) studies to assess the impact of chemical contaminants (e.g., Brown, 2009; Yu et al., 2011).

8.1.3 Laboratory ecotoxicity testing

Ecotoxicity tests are designed to examine if either a potentially toxic chemical, or an environmental sample (e.g., soil, water), causes a biologically important response (either lethal or sublethal) in test organisms (ISO, 2006). Ecotoxicity tests usually measure either:

- the proportion of organisms affected, or
- the degree of effect shown following exposure to a chemical.

Laboratory ecotoxicity tests use controlled, standardised methodologies of exposing a test species to soil, sediment, or water[31] spiked with a known quantity of chemical and recording the predetermined measurement effect over a defined period of time. These tests are relatively simple, easy to standardise and are reproducible. Laboratory studies allow for direct, cause-and-effect (or concentration-response) assessment because they are conducted in a controlled environment.

Test solutions usually cover a geometrically increasing series of concentrations (known as serial dilutions). Ideally, a range finding study is performed prior to the ecotoxicity test to identify the lowest concentration where no toxic effects are observed and the highest concentration where close to 100% effects are observed. Control and reference toxicant tests are also performed to satisfy quality control requirements.

Ecotoxicity tests offered by Australian commercial laboratories are in conformance with the requirements of the following guidelines:

- American Society for Testing and Materials (ASTM) Standard Guides for toxicity testing
- Organisation for Economic Co-operation and Development (OECD) Test Guidelines for ecotoxicity testing https://www.oecd.org/env/ehs/testing/seriesontestingandassessmentecotoxicitytesting.htm.Organisation for Economic Co-operation and Development (OECD) Test Guidelines for ecotoxicity testing https://www.oecd.org/env/ehs/testing/seriesontestingandassessmentecotoxicitytesting.htm.
- Australian and New Zealand Guidelines for Fresh and Marine Water, 2018 (ANZG), and
- Simpson and Batley, 2016. Sediment Quality Assessment: a practical guide. Second Edition. CSIRO.

These ecotoxicity testing guidelines preclude the use of turtles as test species. Furthermore, standard ecotoxicity tests methods for turtles (and all reptiles) are not well developed globally (GoC, 2010). Freshwater toxicity tests generally offered by commercial laboratories in Australia are summarised in Table 8-1.

[31] Vapour inhalation is generally not considered to be a significant exposure pathway for terrestrial animals and therefore ecotoxicity tests specifically assessing the vapour inhalation pathway are not commonly undertaken.

Table 8-1 Common freshwater ecotoxicity tests

Species	Test Name	Description
Algae	72-hr *Selenastrum capricornutum* growth inhibition	This chronic toxicity test involves exposing laboratory cultured algae to the test material for 72 hours. The test is usually undertaken on a range of concentrations of a test material, e.g., 100, 50, 25, 12.5 and 6.3% effluent. At the end of the exposure period, algae cell yield is determined. Statistical analyses are then applied to the test data to determine for example, the concentration of the test material causing 50% inhibition in algal cell yield in the test population (IC50 estimate). The test data can then be used to estimate concentrations of the test material likely to cause chronic toxicity in the environment.
Duckweed	7-day *Lemna disperma* growth test	This chronic toxicity test involves exposing laboratory cultured duckweed to the test material for 7 days. The test is usually undertaken on a range of concentrations of a test material, e.g., 100, 50, 25, 12.5 and 6.3% effluent. At the end of the exposure period, specific growth rate and frond dry weight are determined. Statistical analyses are then applied to the test data to determine for example, the concentration of the test material causing 50% inhibition in specific growth rate in the test population (IC50 estimate). The test data can then be used to estimate concentrations of the test material likely to cause chronic toxicity in the environment.
Cladoceran	48-hr acute *Ceriodaphnia dubia* survival	This acute test involves exposing laboratory reared juvenile *Ceriodaphnia* to the test material for 48 hours. The test is usually undertaken on a range of concentrations of a test material, e.g., 100, 50, 25, 12.5 and 6.3% effluent. At the end of the exposure period, the number of surviving *Ceriodaphnia* is counted. Statistical analyses are then applied to the test data to determine for example, the concentration of the test material causing 50% mortalities in the test population (LC50 estimate). The test data can then be used to estimate concentrations of the test material likely to cause acute toxicity in the environment.
	7-day *Ceriodaphnia dubia* partial life-cycle	This test involves exposing laboratory reared juvenile *Ceriodaphnia* to the test material for 7 to 8 days. The test is usually undertaken on a range of concentrations of a test material, e.g., 100, 50, 25, 12.5 and 6.3% effluent. The test solutions are renewed every day. At the end of the exposure period, the number of surviving *Ceriodaphnia* and the number of young produced are counted. Statistical analyses are then applied to the test data to determine for example, the concentration of the test material causing 50% decrease in number of young produced (LC50 estimate). The test data can then be used to estimate concentrations of the test material likely to cause chronic toxicity in the environment.
Fish	Short term toxicity testing (96-hrs)	This test involves exposing fish larvae to the test material for 96 hours. The test is usually undertaken on a range of concentrations of a test material, e.g., 100, 50, 25, 12.5 and 6.3% effluent. At the end of the exposure period, the number of balanced and the number of un-balanced fish larvae are recorded. Statistical analyses are then applied to the test data to determine for example, the concentration of the test material causing 50% reduction in unbalanced fish in the test population (EC50 estimate). The test data can then be used to estimate concentrations of the test material likely to cause acute toxicity in the environment.
	7-day imbalance and growth	
	10-day rainbowfish embryo development and survival	The 10-day embryo development and survival assay is based on a similar USEPA test Method 1001.0: Fathead Minnow Embryo-larval Survival and Teratogenicity test. The test is usually undertaken on a range of concentrations of a test material, e.g., 100, 50, 25, 12.5 and 6.3% effluent. The number of embryos successfully emerged at around Day 6 and the number of surviving larval fish at Day 10 are recorded. Statistical analyses are then applied to the

Species	Test Name	Description
		test data to determine for example, the concentration of the test material causing 50% reduction for both embryo emergence and survival endpoints (EC50 estimates). The test data can then be used to estimate concentrations of the test material likely to cause chronic toxicity to fish in the environment and for SSD calculations without the need for an acute: chronic application factor.

Notes:
IC50 – the concentration of a chemical that is estimated to produce a 50% inhibition of the response being measured when compared with the control response.
LC50 – Median Lethal Concentration – concentration of chemical in water that is estimated to be lethal to 50% of the test organisms when compared to the control response.
EC50 – Median effective concentration – concentration of chemical in water that is estimated to be effective in producing a change in the response being measured in 50% of the test organisms when compared to the control response.

8.2 Relevance of existing ecotoxicity data to freshwater turtles

Ecotoxicity testing used for establishing generic water quality guidelines and chemical risk is performed on a range of species that represent polar, temperate, and tropical environments. Ideally ecotoxicity tests generate data applicable to all life stages of an organism including eggs, juveniles and adults. There is no single 'sensitive' test species because different species will react differently to chemicals. Therefore, ecotoxicity tests are performed for a range of test species from different taxonomic groups that represent different trophic levels (e.g., fish, invertebrates, plants) to understand how a chemical may affect an ecosystem.

Certain species are frequently used in ecotoxicity testing because their physiology and life histories are well understood, they are common in the environment, easy to catch and/or they are easily maintained and bred in captivity. Common freshwater test species are presented in Table 8-1. Standardised testing procedures have been developed for a few common test species enabling greater reproducibility and certainty in the interpretation of ecotoxicity data (refer to Section 8.1.3).

In Australia, ecotoxicological studies of freshwater turtles are rare and generally have not conclusively established links between contaminant concentrations in tissues and subsequent pathologies (e.g., Browne, 2009). This paucity of data is reflected in the ANZG (2018) aquatic toxicology summaries for toxicants (e.g., metals and metalloids, organic compounds) and associated default guideline value (DGV). Specific toxicity data for freshwater turtles are absent in these guidelines.

However, the existing ANZG (2018) aquatic water quality guidelines for chemicals are expected to be protective of turtle populations because these water quality guidelines are designed to protect ecosystems comprising water-breathing animals (including fish and invertebrates). While turtles are air-breathing and water breathing, evidence indicates that water column exposure to chemicals via cloacal respiration is the most significant pathway for chemical exposure (Limpus et al., 2011a).

In this sense, ANZG DGV may provide some protection for turtle populations, as vertebrate water breathing taxa: amphibians and especially fish, comprise test animals used in guideline derivation (Warne et al, 2018). In terms of dietary and drinking water intake exposure pathways, ANZG values (particularly those protective of indirect bioaccumulation effects) are considered protective of wildlife (such as semi-aquatic reptiles) in the Australasian framework (ANZECC, 2000 *Aquatic and semiaquatic reptiles and waterbirds*, p 8.1 – 14; ANZG, 2018, *Terrestrial and semi-terrestrial wildlife drinking water*, https://www.waterquality.gov.au/anz-guidelines/guideline-values/default).

Furthermore, since the freshwater turtles lay their eggs on higher banks within the Dawson River and riparian vegetation (i.e., not submerged in river water) or saturated sediments (refer to Section 8.1.1), exposure to chemicals in river water from desalinated water during embryo development is expected to be negligible.

Obtaining ecotoxicity data for all species in an ecosystem is not a realistic or practical goal, and certain taxa will be prohibitive to test based on animal ethics, legal and logistical limitations. Extrapolation of ecotoxicity data generated from laboratory species to relevant species in the field, and to whole ecosystems, introduces uncertainties in the estimation of potential risks. The guideline derivation frameworks, which require minimum numbers of phyla or trophic levels in testing (and/or compensatory interspecies assessment factors) introduce considerable conservatism into these extrapolations.

With recognition of these limitations, it is generally considered that ecotoxicity results from a range of standardised test species will be representative of ecotoxicity experienced by all wildlife within an ecosystem i.e., ecotoxicity data for freshwater algae, invertebrates and fish will be representative of ecotoxicity to freshwater turtles (ANZG, 2018). Generally, test organisms such as *Daphnia* and algae are expected to be more sensitive than vertebrate animals. Furthermore, although these studies do not directly address the impact of toxicants upon turtles, they are nevertheless relevant, as they relate to a diversity of freshwater aquatic taxa important in the productivity of the environment that turtles inhabit.

8.3 Chemical risk assessment

8.3.1 Chemical risk assessment framework

A Chemical Risk Assessment Framework (CRAF) was developed for the risk assessment of chemicals proposed to be used in coal seam gas operations (drilling and completions, hydraulic fracturing and water treatment) that may be potentially released to surface waters of the Dawson River via desalinated water releases. The CRAF is provided in Appendix I-1.

The Fairview Water Release Scheme CRAF (Appendix I-1) incorporates the best practice risk assessment methodology for chemicals used and proposed to be used in, or arising from, CSG operations on MNES and aligns with chemical assessment guidance provided by:

- Australian Industrial Chemicals Introduction Scheme (AICIS) (formerly National Industrial Chemicals Notifications and Assessment Scheme (NICNAS)) and approach used for industrial chemicals.
- Department of the Environment, Water, Heritage and the Arts [DEWHA – now DCCEEW] (2009). Environmental risk assessment guidance manual for industrial chemicals, Department of the Environment, Water, Heritage and the Arts, Commonwealth of Australia.
- Department of the Environment and Energy [DoEE – now DCCEEW]. (2017). Environmental risks associated with surface handling of chemicals used in coal seam gas extraction in Australia, Project report prepared by the Chemicals and Biotechnology Assessments Section (CBAS), in the Chemicals and Waste Branch of the Department of the Environment and Energy as part of the National Assessment of Chemicals Associated with Coal Seam Gas Extraction in Australia, Commonwealth of Australia, Canberra.
- NICNAS 2017, Human health risks associated with surface handling of chemicals used in coal seam gas extraction in Australia, Project report prepared by the National Industrial Chemicals Notification and Assessment Scheme (NICNAS) as part of the National Assessment of Chemicals Associated with Coal Seam Gas Extraction in Australia, Commonwealth of Australia, Canberra.
- enHealth (2012a) Environmental health risk assessment: Guidelines for assessing human health risks from environmental hazards, enHealth Subcommittee (enHealth) of the Australian Health Protection Principal Committee, Canberra, Australia.
- enHealth (2012b) Australian exposure factor guidance, enHealth Subcommittee (enHealth) of the Australian Health Protection Principal Committee, Canberra, Australia

The CRAF also aligns with the approved GFD Project area Chemical Risk Assessment Framework (EPBC 2012/6615) as published on Santos' website.

For the purposes of Fairview Water Release Scheme CRAF, drilling and completion, hydraulic fracturing and water treatment chemicals and geogenic constituents have been considered to have the potential to be present in the influent to the water treatment plant and therefore the potential to discharge to the Dawson River after treatment.

In accordance with the CRAF, formal assessments must be conducted on each chemical used. The aim of the chemical risk assessment(s) is to evaluate the potential risks and effects of chemicals used during coal seam gas operations (defined as drilling and completion, hydraulic fracturing and water treatment) to MNES (including beneficial uses of water) associated with the controlled release of treated water to the Dawson River. The aim of the chemical risk assessment(s) is to also evaluate the potential risks and effects of geogenic chemicals to MNES within the Dawson River that may be present in produced waters during coal seam gas operations.

The goal of the chemical risk assessments is to demonstrate that potential risks to MNES associated with the chemicals used in coal seam gas operations have been eliminated or reduced as much as is reasonably practicable.

This best practice assessment methodology is designed to align with national guidance and other regulatory frameworks and assesses the full lifecycle of chemicals that are stored, handled, used and/or disposed during or following project activities.

The framework for the chemical risk assessment involves a two-step process:

- Step 1 – classification of chemicals
- Step 2 – assessment of chemicals.

The criteria to be used in the chemical category classification within this framework is provided in Appendix I-1 of the CRAF.

Based on the category classification of the chemical (and its potential toxicity, persistence and bioaccumulation potential in the environment), different levels of assessment are conducted with the most robust assessment conducted on the highest classification. Consistent with the screening matrix in Appendix I-1 of the CRAF:

- Tier 1 chemicals, are considered to be of low toxicity and low hazard and require only a screening assessment (Tier 1 assessment) to assess potential risk.
- Tier 2 chemicals, in addition to the screening assessment, will be subjected to a qualitative risk assessment (Tier 2 assessment).
- Tier 3 and Tier 4 chemicals will be subject to an additional quantitative risk assessment with Tier 4 chemicals requiring an additional site-specific quantitative risk assessment.
- Tier 5 chemicals will not be used for the Project.
- In the development of the screening assessment, toxicological profiles have been developed for all chemicals. Depending on the category of the chemical being assessed (i.e., Tier 1, 2, 3 or 4), the toxicological profiles are to include chemical identification, physical and chemical properties, environmental fate properties, human health and environmental hazard assessments, derivation of non-cancer and cancer screening levels, a persistent, bioaccumulative and toxic (PBT) assessment, and regulatory status.
- Consistent with the CRAF, chemicals categorised as Tier 1 or Tier 2 chemicals are designated as 'low risk' chemicals. Chemicals categorised as Tier 3, Tier 4 or Tier 5 chemicals are designated as 'high risk' chemicals.

Chemical risk assessments for Tier 1, 2 and 3 chemicals associated with upstream processes associated with (but not part of) the proposed action is provided in Appendix I-2.

8.3.2 Updated conceptual exposure model

An essential component of the chemical risk assessment is the conceptual exposure model (CEM) that describes the chemical source(s), pathways of chemical migration through environmental media and the potential susceptible populations (both human and ecological) that may be exposed.

The list of exposure pathways associated with the proposed action and subject to the chemical risk assessment process, is provided in Appendix 8 of the CRAF summarised in Table 8-2. In the development of these exposure pathways current environmental setting and land uses, environmental fate and transport mechanisms, and life cycle stages of usage of chemicals and relevant receptors were evaluated to determine which pathways are potentially complete and identify potential receptors for those pathways. A complete exposure pathway exists when a source, a migration pathway, a mechanism for exposure and a potential receptor are all present. If one or more of these elements are missing, potential risks to human or ecological receptors cannot occur.

These exposure pathways have been evaluated as part of qualitative assessments (Tier 2) and quantitative risk assessments (Tier 3). If an exposure pathway is deemed to be not complete for a specific chemical, this is discussed in the chemical specific risk assessment.

The potentially complete exposure pathways compiled for the chemical risk assessments are based on the specific release modes for each of the lifecycle phases and the potentially MNES-exposed affected environment within the proposed action area. The potential MNES receptors likely to be in contact with desalinated water releases to the Dawson River are the freshwater MNES turtles *E. albagula* and *R. leukops* and GDE species including *E. populnea* and *E. tereticornis*.

In accordance with the conceptual exposure model provided in the CRAF, exposures have been categorised either:

- Complete exposure (C) – when a source, a migration pathway, a mechanism for exposure and a potential receptor are present.
- Incomplete exposure (IC) – when any one or more of the four elements (source, pathway, mechanism and receptor) that make a complete exposure pathway are not present.
- Insignificant / low probability exposure (I/LP) – where the potential risks are limited due to attenuation, fate and transport mechanisms, infrequent exposure occurrence, and / or minimal projected chemical concentrations at the point of exposure (i.e., there is no hazard).

For MNES values to be included in the risk assessment process there must be:

- the potential for MNES values to be present (receptor) and an exposure pathway to the chemical additive(s) from an authorised activity, or
- the potential for MNES values to be present (receptor) and an exposure pathway to media (soils or water resources (surface or groundwater)) affected by an authorised activity

For a non-MNES value(s) to be included in the risk assessment there must be:

- a non-MNES water resource (surface water and / or groundwater) affected or potentially affected by chemical additive(s) from an authorised activity, and
- a complete or potentially complete exposure pathway to the non-MNES receptor.

Using this framework, the CRAF outlined potentially complete exposure scenarios that needed to be considered as part of the qualitative (Tier 2) and quantitative (Tier 3 and Tier 4) risk assessments.

Table 8-2 Conceptual exposure pathways (Dawson River CRAF)

	Lifecycle Primary Source	Potential Residual Drilling and Completion, Hydraulic Fracturing and Water Treatment Plant Chemical Exposure
	Modes of Exposure	**Release of Desalinated Water**
Affected Media/ Environment	Stored Fluids/Produced Water	IC
	Soils	IC
	Surface Water	C
	Groundwater	IC
Stored Fluids/Produced Water		
Human Receptors	Worker	-
Ecological Receptors	Terrestrial flora	-
	Terrestrial fauna	-
	Aquatic flora	-
	Aquatic fauna	-
Soils		
Human Receptors	Worker	-

	Lifecycle Primary Source	Potential Residual Drilling and Completion, Hydraulic Fracturing and Water Treatment Plant Chemical Exposure
	Modes of Exposure	**Release of Desalinated Water**
	Agricultural Worker or Resident	-
Ecological Receptors	Terrestrial flora	-
	Terrestrial fauna	-
	Aquatic flora	-
	Aquatic fauna	-
Surface Water		
Human Receptors	Worker	NA
	Agricultural Worker or Resident	I/LP
Ecological Receptors	Terrestrial flora	C
	Terrestrial fauna	C
	Aquatic flora	C
	Aquatic fauna	C
Groundwater		
Human Receptors	Worker	-
	Agricultural Worker or Resident	-
Ecological Receptors	Terrestrial flora	-
	Terrestrial fauna	-
	Aquatic flora	-
	Aquatic fauna	-

Notes:
C Complete exposure pathway
IC Incomplete exposure pathway
I/LP Insignificant / Low Probability Exposure Pathway
NA Not a Matter of National Environmental Significance (MNES)

8.3.3 Chemical risk assessment summary

Santos engaged EHS Support to prepare the chemical risk assessments (Appendix I-2) in accordance with the CRAF (Appendix I-1). As presented in the Register of Assessed Chemicals included in Appendix I-2,146 Tier 1 chemicals, 25[32] Tier 2 chemicals (Table 8-3) and 12 Tier 3 chemicals (Table 8-4) were assessed[33]. Three (3) chemicals were deemed to be impurities at de minimus levels within a proposed product (CAS No 4080-31-3). No chemicals were assessed as Tier 4 or 5 chemicals.

Depending on the category of the chemical assessed (i.e. Tier 1, 2, 3 or 4), the toxicological profiles (dossiers) include:

- chemical identification
- physical and chemical properties
- environment fate properties

[32] Boric acid and sodium tetraborate decahydrate (borax) included in the same Tier 2 assessment
[33] Consistent with the CRAF, new chemicals identified following the submittal of this initial chemical risk assessment will be appended to this document.

- human health and environmental hazard assessments
- derivation of non-cancer and cancer screening levels
- persistent, bioaccumulative and toxic (PBT) assessment
- calculation of a Predicted No-Effects Concentrations (PNECs) for water, sediment, and soil
- comparison of theoretical chemical concentrations (for desalinated water release) against the PNEC, and
- regulatory status.

Toxicological profiles for Tier 1 chemicals are provided in Appendix I-2.

In addition to the toxicological profile, Tier 2 chemicals were also subject to a qualitative risk assessment. Tier 3 chemicals were subject to a quantitative risk assessment. Tier 3 assessments also include a quantitative risk characterisation for a number of fauna such as birds (cattle egret) and mammals (kangaroo, dingo and cattle). The chemical risk assessments completed by EHS Support for the Tier 2 and Tier 3 chemicals are also provided in Appendix I-2.

The Tier 2 and Tier 3 chemicals that have been subject to a qualitative and/or quantitative risk assessment are discussed further.

Table 8-3 and Table 8-4 summarise the following information for Tier 2 and Tier 3 chemicals, respectively:

- PNECs for freshwater[34] considered to be protective of aquatic receptors. PNECs were calculated by dividing the lowest ecotoxicity endpoint (i.e., EC50[35] or NOEC[36]) by an assessment factor (AF). The AF was selected based on the quality and quantity of the ecotoxicity data set (i.e., lower AF for more reliable chronic data and a higher AF for low reliability acute data), and
- PBT classification.

An assessment of whether a potentially complete exposure pathway is presented to inform the assessment of potential risk to turtles from exposure to chemicals in the release water. An exposure pathway was considered to be incomplete if one or more of the following elements were not present: source, migration pathway, mechanism for exposure and the presence of a potential receptor. An incomplete pathway precludes an exposure and associated potential risk from occurring. Conversely, a pathway was considered to be potentially complete if a source, migration pathway, mechanism and a potential receptor are present. The exposure pathway assessments were performed by EHS Support.

[34] Sediment PNECs are detailed in the toxicological profiles (dossiers) provided for each Tier 2 and Tier 3 chemical in Appendix I.
[35] Effective Concentration (EC) which affects 50 % of the test population
[36] No Observed Effect Concentration (NOEC)

Table 8-3 Ecotoxicity summary for Tier 2 chemicals

Chemical name	CAS No.	Endpoint	Test species	EC_{50} or NOEC (mg/L)	Assessment Factor	$PNEC_{water}$ (mg/L)	PBT	Potentially Complete Exposure Pathway
2-Mercaptoethanol	60-24-2	Reproduction (chronic)	*Daphnia magna* (crustacean)	0.063	50	0.0013	No	Yes
Alcohols, C12-16, ethoxylated	68551-12-2	-		-	-	0.14[A]	No	Yes
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	Reproduction (chronic)	*Daphnia magna* (crustacean)	0.07	10	0.007	No	Yes
Amine Oxides, cocoalkyldimethyl	61788-90-7	Growth rate (chronic)	*Selenastrum capricornutum* (green algae)	0.09	10	0.009	No	Yes
Benzaldehyde	100-52-7	Growth rate and mortality (chronic)	*Pimpephales promelas* (fish)	0.12	50	0.002	No	Yes
Benzyl-C1-2-alkylpyridinium chloride	68909-18-2	Growth rate (acute)	*Peudokirchneriella subcapitata* (algae) *Daphnia magna* (crustacean)	0.47	1,000	0.0005[B]	No	Yes
Chlorous acid, sodium salt (or sodium chlorite)	7758-19-2	Growth rate (acute)	*Peudokirchneriella subcapitata* (algae)	1	1,000	0.001	No	Yes
Cocamidopropyl betaine	61789-40-0	Mortality (chronic)	*Oncorhynchus mykiss* (fish)	0.16	50	0.0032	No	Yes
Hydrocarbons, C12-C15, n-alkanes, isoalkanes, cyclics, <2 % aromatics	64742-47-8	Reproduction (chronic)	*Daphnia magna* (crustacean)	0.48	100	0.005[C]	No	Yes

Chemical name	CAS No.	Endpoint	Test species	EC_{50} or NOEC (mg/L)	Assessment Factor	$PNEC_{water}$ (mg/L)	PBT	Potentially Complete Exposure Pathway
Hydrogen Peroxide	7722-84-1	Reproduction (chronic)	Skeletonema costatum (algae) *Dahnia magna* (crustacean)	0.63	50	0.013	No	No. Membrane cleaning waste is directed to the brine dams where hydrogen peroxide will rapidly break down. As a result, this chemical would not be present in desalinated water or brine. Therefore, exposure pathways associated with Dawson River release would be incomplete.
PolyDADMAC	26062-79-3	Mortality (acute)	Fathead minnow (fish)	6.5	50	0.13	No	No. The cationic polymers would be bound to the solids present in the oily water and removed during clarification. As a result, this chemical would not be present in brine or desalinated water. Therefore, exposure pathways associated with Dawson River release would be incomplete
Polyquaternium-33	69418-26-4	Mortality (acute)	Species not specified (fish)	1-10	1000	0.001-0.01	No	No. The cationic polymers would be bound to the solids present in the oily water and removed during clarification. As a result, this chemical would not be present in brine or desalinated water. Therefore, exposure pathways associated with Dawson River release would be incomplete.
Boric Acid	10043-35-3	-		-	-	0.94[D]	No	Yes

Chemical name	CAS No.	Endpoint	Test species	EC_{50} or NOEC (mg/L)	Assessment Factor	$PNEC_{water}$ (mg/L)	PBT	Potentially Complete Exposure Pathway
Sodium Tetraborate Decahydrate (Borax)	1303-96-4	-		-	-	0.94[D]	No	Yes
Ammonium hydroxide	1336-21-6	-	-	-	-	0.9[E]	No	Yes
C10-C16 Alkylbenzenesulfonic acid	68584-22-5	-	-	-	-	0.28[F]	No	Yes
Calcium carbide	75-20-7	Reproduction (acute)	*Daphnia magna* (crustacean)	4.62	1000	0.0046	No	No This chemical instantly decomposes hydrolytically with a hydrolysis half-life of less than 1 minute. As a result, this chemical would not be present in treated water. Therefore, exposure pathways associated with Dawson River release would be incomplete
Amides, coco, N,N-bis (hydroxyethyl)	68603-42-9	Mortality (acute)	*Daphnia pulex* (crustacean)	2.15	1000	0.002	No	Yes
3,5,7-Triaza-1-azoniatricyclo[3.3.1.13,7]decane,1-(3-chloro-2-propenyl)- , chloride (CTAC)	4080-31-3	Growth rate (acute)	*Peudokirchneriella subcapitata* (algae)	1.5	1000	0.0015	No	Yes
Ethyl hexanol	104-76-7	Growth rate (acute)	*Scenedesmus subspicatus* (green algae)	11.5	1000	0.012	No	Yes
Monoethanolamine	141-43-5	Growth rate (chronic)	*Peudokirchneriella subcapitata* (algae)	0.7	10	0.07	No	Yes

Chemical name	CAS No.	Endpoint	Test species	EC_{50} or NOEC (mg/L)	Assessment Factor	$PNEC_{water}$ (mg/L)	PBT	Potentially Complete Exposure Pathway
Oxazolidine	66204-44-2	Mortality (chronic)	*Daphnia magna* (crustacean)	1.3	50	0.026	No	Yes
Ethoxylated alcohol	78330-21-9	-	-	-	-	0.14[A]	No	Yes
Alkanes, C11-15-iso-	90622-58-5	-	-	-	-	0.001[G]	No	Yes
Isotridecanol, ethoxylated	69011-36-5	-	-	-	-	0.14[A]	No	Yes

Notes:
NA – Not Applicable. PNEC not established
A – ANZG (2018) Water Quality Guideline – Freshwater Trigger Value for alcohol ethoxylates
B – The studies were conducted using humic acid diluted in water
C – A No Observed Effect Level (NOEL) for hydrodesulfurised kerosine was used as the point of departure
D – ANZG (2021) Water Quality Guideline – Freshwater Default Guideline Value for boron
E - ANZG (2018) Water Quality Guideline – Freshwater Default Guideline Value for total ammonia-N
F – ANZG (2018) Water Quality Guideline – Freshwater Trigger Value for linear alkylbenzene sulfonate (LAS)
G – PNEC estimated using the quantitative structure activity relationship (QSAR) model PETRORISK v7.04

Table 8-4 Ecotoxicity summary for Tier 3 chemicals

Chemical name	CAS No.	Endpoint	Test species	EC50 or NOEC (mg/L)	Assessment Factor	PNECwater (mg/L)	PBT	Potentially Complete Exposure Pathway?
Aluminum Hydroxychloride	1327-41-9	-		-	-	0.0008[A]	No	No. Aluminium hydroxychloride would be bound to the solids present in the oily water and removed during clarification. As a result, this chemical would not be present in brine or desalinated water. Therefore, exposure pathways associated with Dawson River release would be incomplete. Further information is presented in Appendix I-2
Cocoalkyl dimethylbenzyl ammonium chloride (ADBAC)	61789-71-7	Reproduction (chronic)	*Daphnia magna* (crustacean)	0.00415	10	0.000415	No	Yes
Dialuminium Chloride Pentahydroxide	12042-91-0	-	-	-	-	0.0008[A]	No	No. Dialuminium chloride pentahydroxide is removed with Actiflo sludge (solid waste) during water treatment. As a result, this chemical is not directed to the desalinated water or brine waste streams and would not be present in brine or desalinated water. Therefore, exposure pathways associated with Dawson River release would be incomplete. Further information is presented in Appendix I-2.
Glutaraldehyde	111-30-8	Growth rate (chronic)	*Scenedesmus subspicatus* (algae)	0.025	10	0.0025	No	Yes
Hydrochloric Acid	7647-01-0	Growth rate (acute)	*Chlorella vulgaris* (algae)	0.36	NA	NA[B]	No	No. Hydrochloric acid dissociates completely in aqueous media to hydrogen (H+) and chloride (Cl-) ions. Both

Chemical name	CAS No.	Endpoint	Test species	EC50 or NOEC (mg/L)	Assessment Factor	PNECwater (mg/L)	PBT	Potentially Complete Exposure Pathway?
								ions are ubiquitous in the environment. As a result, this chemical would not be present within the water feed pond. Likewise, during water treatment it would be removed by the reverse osmosis system, with the majority directed to brine (i.e., less than 5% to desalinated water). Therefore, exposure pathways associated with Dawson River release would be incomplete. Further information is presented in Appendix I-2.
Peroxyacetic Acid	79-21-0	Mortality (chronic)	*Danio rerio* (fish)	0.002	10	0.0002	No	No. Membrane cleaning waste is directed to the brine dams where peroxyacetic acid will rapidly break down. As a result, this chemical would not be present in brine or desalinated water. Therefore, exposure pathways associated with Dawson River release would be incomplete. Further information is presented in Appendix I-2.
Sodium Hypochlorite	7681-52-9	-	-	-	-	0.003[C]	No	No. Sodium hypochlorite fully dissociates to sodium (Na) and chloride (Cl), with Na and Cl removed by the reverse osmosis system at 95% to the brine and 5% stays within desalinated water. Sodium concentrations are de minimis (< 10 mg/L) in the desalinated water and <80 mg/L in the brine, both of which are less than geogenic background. As a result, this chemical was not evaluated further in brine or desalinated water. Therefore, exposure pathways associated with Dawson River release would be incomplete. Further information is presented in Appendix I-2.

Chemical name	CAS No.	Endpoint	Test species	EC50 or NOEC (mg/L)	Assessment Factor	PNECwater (mg/L)	PBT	Potentially Complete Exposure Pathway?
Tributyl tetradecyl phosphonium chloride	81741-28-8	Growth rate (acute)	*Selenastrum capricornutum* (algae)	0.019	1000	0.000019	No	Yes
Mixture of 5-chloro-2-methyl-2h-isothiazolol-3-one (CMIT) and 2-methyl-2h-isothiazol-3-one (MIT)	55965-84-9	Growth rate (chronic)	*Skeletonema costatum* (algae)	0.0014	10	0.00014	No	Yes
2,2-Dibromo-3-Nitrilopropionamide (DBNPA)	10222-01-2	Reproduction (chronic)	*Daphnia magna*	0.05	50	0.001	No	No. DBNPA hydrolyses rapidly in natural waters to many degradants which continue to degrade rapidly by aerobic and anaerobic aquatic metabolism. These degradants would be removed by the reverse osmosis system, with the majority directed to brine (i.e., less than 5% to desalinated water) and subject to further degradation. Therefore, exposure pathways associated with Dawson River release would be incomplete. Further information is presented in Appendix I-2.
Cupric Nitrate	3251-23-8	-	-	-	-	0.0014[D]	No	No. Cupric nitrate is present as a stabiliser in the HCS04 ROP product at a *de minimis* concentration of <0.5 %. In aqueous solution, cupric nitrate fully dissociates to copper (Cu^{2+}) and nitrate (NO_3^-) anions. During the treatment process, these anions would be removed by the reverse osmosis system, with the majority directed to brine (i.e., less than 5% to desalinated water) and subject to immobilisation. Concentrations of dissolved

Chemical name	CAS No.	Endpoint	Test species	EC50 or NOEC (mg/L)	Assessment Factor	PNECwater (mg/L)	PBT	Potentially Complete Exposure Pathway?
								copper have been detected three times (max 0.003 µg/L) in 137 samples taken between April 2015 and October 2021. Therefore, exposure pathways associated with Dawson River release would be incomplete. Further information is presented in Appendix I-2.
Dibromoacetonitrile	3252-43-5	Mortality (acute)	*Fathead minnow (Pimephales promelas)*	0.55	1000	0.00055	No	No Dibromoacetonitrile is present in the biocide product at *de minimus* levels (<1%) and hydrolyses rapidly. The hydrolysis breakdown products is then removed by the reverse osmosis system, with the majority directed to brine (i.e., less than 5% to desalinated water) and subject to further degradation. Therefore, exposure pathways associated with Dawson River release would be incomplete. Further information is presented in Appendix I-2.

Notes:
NA – Not Applicable. PNEC not established
A – ANZG (2018) Water Quality Guideline – Freshwater Default Guideline Value for aluminium
B – PNEC not established. Lowest reported EC10 value for algae
C – ANZG (2018) Water Quality Guideline – Freshwater Default Guideline Value for chlorine
D - ANZG (2018) Water Quality Guideline – Freshwater Default Guideline Value for copper

As indicated in Table 8-3 and Table 8-4, of all Tier 2 and Tier 3 chemicals with the potential to be present in treated desalinated water had potentially complete exposure pathways to aquatic ecosystems of the Dawson River including MNES freshwater turtles. Aquatic ecological species (including MNES freshwater turtles) within Dawson River downstream of the waterhole confluence are considered potential receptors with a complete pathway due to desalinated water releases to the Dawson River.

To further assess the Tier 2 and Tier 3 chemicals with complete exposure pathways, quantitative mass balance calculations were performed by EHS Support to estimate potential exposure point concentrations (EPCs) at the following locations and release scenarios:

- Produced water management pond influent concentrations
- Water management pond concentrations (prior to treatment)
- Dawson River surface water and sediment (after treatment via desalinated water releases).

Details of the mass balance concentrations are provided in the chemical risk assessments presented in Appendix I-2.

Comparison of the theoretical conservative EPCs (assuming no biodegradation) and the water PNECs for each Tier 2 and Tier 3 chemical identified as having a complete source-pathway-receptor linkage is provided in Table 8-5. Of the 25 Tier 2 and 12 Tier 3 chemicals summarised in Table 8-5, none had EPCs for (treated) desalinated water greater than PNECs. In other words, none of the predicted Tier 2 and Tier 3 chemical concentrations in treated desalinated water released to the receiving environment were above a concentration that is expected to be ecologically toxic.

The chemical risk assessments completed for each chemical indicated no significant risks and effects of chemicals used to MNES when appropriate management and mitigation controls were in place. No potential risks were also identified for non-MNES receptors.

In general, the management practices adopted and implemented by Santos are appropriate and have eliminated or reduced as much as is reasonably practicable the potential risks to MNES (and non-MNES) associated with the chemicals used.

Table 8-5 Comparison of predicted no-effects concentrations (PNEC) and theoretical exposure point concentrations (EPC)

Chemical name	CAS No.	Tier	PNEC water (mg/L)	EPC in Water Management Pond (Influent)* (mg/L)	EPC in Dawson River (Desalinated Release)* (mg/L)	Notes
Alcohols, C12-16, ethoxylated	68551-12-2	2	1.40E-01	2.00E-02	4.00E-06	The potential for exposure of sensitive receptors, including MNES, is low. EPC in Dawson River is less than PNEC.
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	2	7.00E-03	6.80E-02	1.36E-05	The potential for exposure of sensitive receptors, including MNES, is low. EPC in Dawson River is less than PNEC.
Amine Oxides, cocoalkyldimethyl	61788-90-7	2	9.00E-03	1.05E-01	2.11E-05	The potential for exposure of sensitive receptors, including MNES, is low. EPC in Dawson River is less than PNEC.
Benzaldehyde	100-52-7	2	2.00E-03	4.80E-02	9.60E-06	The potential for exposure of sensitive receptors, including MNES, is low. EPC in Dawson River is less than PNEC.
Benzyl-C1-2-alkylpyridinium chloride	68909-18-2	2	5E-03	7.2E-10	Not calculated	The potential for exposure of sensitive receptors, including MNES, is low. EPC in WMF influent prior to treatment is less than PNEC.
Chlorous acid, sodium salt (or sodium chlorite)	7758-19-2	2	1E-03	Not calculated	Not calculated	The potential for exposure of sensitive receptors, including MNES, is low. Chlorous acid, sodium salt readily dissociates in aqueous solutions to the sodium (Na^+) and chlorite (ClO_2^-) ion. Chlorite will ultimately degrade to chloride (Cl^-) ions. Residual sodium and chloride ions are ubiquitous in the environment. In addition, residual concentrations in desalinated water are consistent with or less than receiving waters of the Dawson River (refer to chemical risk assessment presented in Appendix I-2 for further information).
2-Mercaptoethanol	60-24-2	2	1.3E-03	1.4E-10	Not calculated	The potential for exposure of sensitive receptors, including MNES, is low. EPC in WMF influent prior to treatment is less than PNEC.
Cocamidopropyl betaine	61789-40-0	2	3.20E-03	1.25E+01	2.50E-03	Cocamidopropyl betaine in untreated water exceeded the PNEC. However, the chemical is susceptible to photolytic degradation (half-life of less than 10 hours), dissociation in aqueous systems and is considered readily biodegradable (>80% after 7 days). EPC in Dawson River is less than PNEC.

Chemical name	CAS No.	Tier	PNEC water (mg/L)	EPC in Water Management Pond (Influent)* (mg/L)	EPC in Dawson River (Desalinated Release)* (mg/L)	Notes
						Therefore, the potential for exposure of sensitive receptors, including MNES is low.
Hydrocarbons, C12-C15, n-alkanes, isoalkanes, cyclics, <2 % aromatics	64742-47-8	2	5.00E-03	1.32E-01	2.64E-05	The potential for exposure of sensitive receptors, including MNES, is low. EPC in Dawson River is less than PNEC.
Boric Acid and Borax	10043-35-3 1303-96-4	2	9.4E-01	Not calculated	Not calculated	Borax will transform into boric acid in the aquatic environment. In the environment boric acid is in equilibrium with borate anions. Both species are very stable as they do not undergo biotransformation or redox reactions under normal environmental conditions. In accordance with EA conditions, release of desalinated water to the Dawson River is monitored for boron (refer to risk assessment presented in Appendix I-2 and water quality summary data in Appendix E-2 for further information).
Cocoalkyl dimethylbenzyl ammonium chloride (ADBAC)	61789-71-7	3	4.20E-04	7.20E-10	1.44E-13	The potential for exposure of sensitive receptors, including MNES, is low. EPC in Dawson River is less than PNEC.
Glutaraldehyde	111-30-8	3	2.50E-03	1.07E-05	2.13E-09	The potential for exposure of sensitive receptors, including MNES, is low. EPC in Dawson River is less than PNEC.
Tributyl tetradecyl phosphonium chloride (TTPC)	81741-28-8	3	1.90E-05	3.76E-03	7.52E-07	The potential for exposure of sensitive receptors, including MNES, is low. EPC in Dawson River is less than PNEC.

Chemical name	CAS No.	Tier	PNEC water (mg/L)	EPC in Water Management Pond (Influent)* (mg/L)	EPC in Dawson River (Desalinated Release)* (mg/L)	Notes
Mixture of 5-chloro-2-methyl-2h-isothiazolol-3-one (CMIT) and 2-methyl-2h-isothiazol-3-one (MIT)	55965-84-9	3	1.40E-04	7.20E-04	1.44E-07	The potential for exposure of sensitive receptors, including MNES, is low. EPC in Dawson River is less than PNEC.
Ammonium hydroxide	1336-21-6	2	9.0E-01	1.75E-02	Not calculated	The potential for exposure of sensitive receptors, including MNES, is low. EPC in the WMF permeate is less than PNEC.
C10-C16 Alkylbenzenesulfonic acid	68584-22-5	2	2.8E-01	1.0E-01	2.0E-05	The potential for exposure of sensitive receptors, including MNES, is low. EPC in Dawson River is less than PNEC.
Amides, coco, N,N-bis (hydroxyethyl)	68603-42-9	2	2.0E-03	3.2E+00	6.4E-04	Amides, coco, N,N-bis (hydroxyethyl) in untreated water prior to biodegradation or treatment exceeded the PNEC. However, the chemical has a low tendency to bind to soil or sediment and is considered readily to inherently biodegradable. EPC in Dawson River is less than PNEC. Therefore, the potential for exposure of sensitive receptors, including MNES, is low.
3,5,7-Triaza-1-azoniatricyclo[3.3.1.1 3,7]decane,1-(3-chloro-2-propenyl)- , chloride (CTAC)	4080-31-3	2	1.5E-03	3.2E-02	6.4E-06	The potential for exposure of sensitive receptors, including MNES, is low. EPC in Dawson River is less than PNEC.
Ethyl hexanol	104-76-7	2	1.2E-02	6.7E+00	1.3E-03	Ethyl hexanol in untreated water prior to biodegradation or treatment exceeded the PNEC. However, the chemical is expected to volatilise from water and is considered readily biodegradable (70% to 100% after 14 days). EPC in Dawson River is less than PNEC. Therefore, the potential for exposure of sensitive receptors, including MNES is low.

Chemical name	CAS No.	Tier	PNEC water (mg/L)	EPC in Water Management Pond (Influent)* (mg/L)	EPC in Dawson River (Desalinated Release)* (mg/L)	Notes
Monoethanolamine	141-43-5	2	7.0E-02	5.0E+00	1.0E-03	Monoethanoamine in untreated water prior to biodegradation or treatment exceeded the PNEC. However, the chemical has a low tendency to bind to soil or sediment and is considered readily biodegradable (>90% after 21 days). EPC in Dawson River is less than PNEC. Therefore, the potential for exposure of sensitive receptors, including MNES, is low.
Oxazolidine	66204-44-2	2	2.6E-02	5.0E+00	1.0E-03	Oxazolidine in untreated water prior to biodegradation or treatment exceeded the PNEC. However, this substance and its hydrolysis products are expected to be extensively removed in aquatic compartments (half-life of hours EPC in Dawson River is less than PNEC. Therefore, the potential for exposure of sensitive receptors, including MNES, is low.
Ethoxylated alcohol	78330-21-9	2	1.4E-01	1.6E-01	3.3E-05	The potential for exposure of sensitive receptors, including MNES, is low. EPC in Dawson River is less than PNEC.
Alkanes, C11-15-iso-	90622-58-5	2	1.0E-03	2.2E-07	Not calculated	The potential for exposure of sensitive receptors, including MNES, is low. EPC in WMF influent prior to treatment is less than PNEC.
Isotridecanol, ethoxylated	69011-36-5	2	1.4E-01	2.2E-07	Not calculated	The potential for exposure of sensitive receptors, including MNES, is low. EPC in WMF influent prior to treatment is less than PNEC.

8.3.4 Cumulative impacts

The potential for cumulative impacts associated with Tier 1 and Tier 2 chemicals used is limited. Residual chemicals may be entrained within produced water and subsequently transported for water treatment at a water treatment plant. However, these chemicals are significantly removed by the treatment systems and, therefore, no additional risk is provided during releases of desalinated water to the Dawson River. Likewise, the presence of water treatment chemicals at the point of desalinated water storage (HCS04DWB1) or during desalinated releases to the Dawson River also poses no significant increase in risk.

Only those Tier 3 chemicals which trigger persistence and bioacummulative thresholds are considered to be chemicals with a potential for cumulative impacts. Only one Tier 3 chemical (TTPC) met the criteria for persistence. None of the Tier 3 chemicals met the criteria for bioaccumulation. Further, estimated concentrations in surface water and sediment were less than PNECs.

Specific discussion on the potential for cumulative impacts is included in the quantitative risk assessments for each Tier 3 chemical in Appendix I-2. As indicated in the assessments provided, evaluation of the chemicals indicates that there is negligible incremental risk posed by their use and the existing management and monitoring controls are appropriate to ensure that the risk to MNES (and non-MNES) receptors remains low.

8.3.5 Geogenic screening assessment

In accordance with the CRAF, a screening level assessment was conducted by EHS Support on geogenic constituents in produced water. This assessment leveraged comprehensive data sets that have been compiled by Santos for existing CSG activities undertaken as part of the GLNG Project. The empirical data are considered representative of geogenic chemicals in produced water that would be returned to the surface through production activities and therefore contained in produced water which may be stored in produced water ponds.

The screening assessment evaluated data against the following criteria for water:

- Human Health
  - National Health and Medical Research Council (NHMRC) National Water Quality Management Strategy, Australian Drinking Water Guidelines (2022)
  - WHO Drinking-water Quality, Fourth Edition (2017)
  - USEPA Regional Screening Levels (RSLs) for tap water (November 2022 update) (2022), and
  - USEPA Maximum Contaminant Levels (USEPA, 2009).
- Environmental and Ecological
  - Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018)
  - Republic of South Africa (1993) South African Water Quality Guidelines
  - USEPA National Recommended Water Quality Criteria (2016), and
  - USEPA Region 3 Biological Technical Assistance Group Freshwater Screening Benchmarks (2011).

The analytical data from produced water was utilised to evaluate potential hazards associated with geogenic chemicals in the desalinated water proposed to be released to the Dawson River.

The arithmetic mean concentrations of geogenic chemicals in produced waters were compared to applicable risk-based human health and ecological screening criteria as a conservative assessment. The arithmetic mean concentration was used in the calculation of the risk ratio with the results summarised in Table 8-6.

Whilst a number of arithmetic mean concentration risk ratios are greater than the target risk ratio (one), the potential for exposure of sensitive receptors including MNES to geogenic chemicals in (untreated) produced water is low and does not form part of the proposed action.

The desalination process is designed to remove geogenic chemicals in produced water to concentrations (i.e., WQOs) protective of aquatic receptors including MNES. Rapid mixing with surface water and base flow further attenuates desalinated water releases within the Dawson River.

Consistent with the CEM, the application of the drinking water criteria is conservative. The Dawson River in the vicinity of the proposed action area is not a domestic water supply source. The nearest surface water domestic water supply entitlement is 244 km downstream (AECOM, 2019). Likewise, there is limited current abstraction of water for agricultural use within the proposed action area though the local land holder does hold a license to use water from the Dawson River (refer to Table 3-3).

Beneficial reuse of water is conducted predominantly by irrigation (60%) as discussed in Section 2.2.2 with 60% of produced water being specifically reused for beneficial use. Site-specific risk assessments are conducted to support activities such as stock watering and land irrigation to ensure risks to receptors are managed and acceptable.

Table 8-6 Summary of risk ratios exceeding target risk ratio for produced water (Fairview WRS)

Chemical Name	Produced Water		
	Drinking Water	Stock Water	Aquatic Ecosystems
Aluminium (Total)	8.0E+00	3.2E-01	2.9E+01
Ammonia as N	8.2E-01	NA	NA
Barium (Total)	8.6E-01	NA	7.8E+00
Boron (Total)	6.2E-01	5.0E-01	2.6E+00
Chloride	5.5E+00	NA	6.0E+00
Copper (Total)	9.3E-04	4.6E-03	1.3E+00
Fluoride	4.1E+00	NA	NA
Iron (Total)	1.1E+00	3.4E-02	3.4E-01
Potassium (Dissolved)	NA	NA	6.2E-01
Sodium (Dissolved)	9.0E+00	8.1E-01	2.4E+00
Zinc (Total)	3.4E-03	5.1E-04	1.3E+00
Lithium (Total)	2.7E+02	NA	NA
Arsenic (Total)	5.7E-01	8.0E-03	1.7E-01
Chromium (Total)	1.3E-01	6.3E-03	6.3E+00
Total Dissolved Solids @180°C (Dissolved)	7.3E+00	1.8E+00	NA
Total Dissolved Solids @180°C (Total)	8.5E+00	2.1E+00	NA

Note:
NA – Not applicable. Either no applicable guideline value exists and/or all reported concentrations below laboratory limit of reporting.

Further discussion of the potential water quality impacts to MNES and water resources is presented in Section 5.0.

9.0 Monitoring, mitigation and management

As described in this revised preliminary document, no significant residual impact has been identified to MNES. Monitoring, mitigation and management of the proposed action will be a continuation of existing monitoring undertaken under the REMP for desalinated water releases.

This section summarises the existing monitoring commitments as follows:

- Section 9.1: Monitoring as documented within the existing State EA and the REMP
- Section 9.2: Detection and response to adverse impacts
- Section 9.3: State EA conditions as applicable to the action

9.1 Monitoring sites

REMP monitoring locations for desalinated water quality, receiving water quality, habitat and ecological assessments are detailed in Table 9-1 and locations are shown on Figure 5-1.

Table 9-1 REMP monitoring locations (after frc Environmental REMP and State EA)

Site	Location	Zone 56, GDA94	
		Latitude	Longitude
Control sites upstream of the receiving environment			
DRR1	Dawson River: 550 m upstream of the confluence of the outlet watercourse and the Dawson River.	-25.688	149.156
Waterbody receiving environment sites			
WLMP1	200 m downstream of where the drainage feature discharges into the Waterbody	-25.708	149.146
WLMP2	450 m upstream of where the drainage feature discharges into the Waterbody	-25.706	149.143
WLMP3	300 m downstream of where the drainage feature discharges into the Waterbody	-25.707	149.149
WLMP4	1.5 km upstream/north of where the drainage discharges into the Waterbody	-25.698	149.139
WLMP5	1.0 km downstream of where the tributary gully discharges into the Waterbody.	-25.701	149.153
Dawson River receiving environment sites			
DRMP1	3.5 km downstream of where the outlet watercourse discharges into the Waterbody and 200 m downstream of the confluence of the outlet watercourse and the Dawson River	-25.6905	149.1675
S4	Dawson River at Yebna Crossing; 9.8 km downstream of where the outlet watercourse discharges into the Waterbody and 8 km downstream of the confluence of the tributary gully and the Dawson River. Represents the downstream extent of the receiving environment	-25.692	149.216
Desalinated water (ROP2) – Treated water			
HCS04DWB1	HCS04 Desalinated Water Dam	-25.730	149.090

9.2 State EA desalinated water monitoring plan

9.2.1 Desalinated water release

Water quality monitoring for HSC04DWB1 and S4 is proposed to continue in accordance with State EA *Schedule B, Table 4 – Contaminant Limits* and *Schedule B, Table 5 Contaminant Limits for protecting the Environmental Value of Drinking Water*, as detailed in Appendix D and Table 9-2.

The State EA CL for protection of EV, including aquatic species protection and drinking water, are presented and discussed in Section 3.4 and Table 3-4

.

Table 9-2 State EA stipulated analytes and monitoring frequency

Desalinated Water Pond HCSO4DWB1			Dawson River Compliance Point S4		
Parameter / Chemical	**Method**	**Frequency**	**Parameter / Chemical**	**Method**	**Frequency**
Temperature	Field readings	Daily during release	Alpha activity	Water sample for NATA accredited laboratory analysis	First release day of each quarter
pH			Aluminium		
Electrical Conductivity			Ammonia		
Turbidity			Arsenic		
Dissolved Oxygen			Barium		
Total Nitrogen	Water sample for NATA accredited laboratory analysis	Weekly during release	Beta activity		
Ammonia			Bisphenol A		
Calcium			Boron		
Chloride			Bromide		
Fluoride			Cadmium		
Magnesium			Chromium		
Potassium			Copper		
Sodium			Cyanide		
Sulphate			Ethylbenzene		
Aluminium			Fluoride		
Total arsenic			Iodide		
Boron			Lead		
Bromide			Manganese		
Cadmium			Mercury		
Chromium (VI)			Molybdenum		
Copper			Nickel		
Iron			Nonylphenol		
Lead			PAH (as BaP TEF)		
Manganese			Selenium		
Mercury			Silver		
Nickel			Strontium		
Selenium			Toluene		
Zinc			TPH		

Desalinated Water Pond HCSO4DWB1			Dawson River Compliance Point S4		
Parameter / Chemical	**Method**	**Frequency**	**Parameter / Chemical**	**Method**	**Frequency**
Hardness			Vanadium		
			Xylenes		
			Zinc		
			Disinfection by-products(#):		
(#)Bromochloroacetonitrile, Dichloroacetonitrile, N-Nitrosodimehtylamine, Trihalomethanes (THM): Bromodichloromethane / Bromoform / Chloroform (Trichloromethane) / Dibromochloromethane.					

9.2.2 Additional Environmental Authority monitoring conditions

Applicable State EA requirements relevant to monitoring desalinated water releases are listed in Table 9-3. The proposed action is the continuation of current desalinated water releases and the same monitoring requirement conditions will be applied to the proposed action. Condition B36 requires the development and implementation of a REMP to "…*to monitor, identify and describe any adverse impacts to surface water environmental values, quality and flows*…". The State EA conditions include notification, actions, and/or response in the event of a CL being exceeded.

Table 9-3 State EA requirements relevant to monitoring the proposed action

Condition #	State EA Requirement
Schedule A - Monitoring	
A5	All monitoring required must be undertaken by a suitably qualified or experienced person (defined in Schedule L)
A8	All laboratory analyses and tests required must be undertaken by a laboratory that has NATA accreditation for such analyses and tests
A9	Notwithstanding condition (A8), where there are no NATA accredited laboratories for a specific analyte or substance, then duplicate samples must be sent to at least two separate laboratories for independent testing or evaluation.
A10	Monitoring and sampling must be carried out in accordance with the requirements of the following documents (as relevant to the sampling being undertaken), as amended from time to time: a) for waters and aquatic environments, the Queensland Government's Monitoring and Sampling Manual Environmental Protection (Water) Policy 2009. b) for groundwater, the Australian Government's Groundwater Sampling and Analysis - A Field Guide and any applicable Australian Standard. f) for soil, the Guidelines for Surveying Soil and Land Resources, 2nd edition (McKenzie et al. 2008), and/or the Australian Soil and Land Survey Handbook, 3rd edition (National Committee on Soil and Terrain, 2009)
A15	The REMP design document must be certified by a suitably qualified person within 30 business days
A16	All plans, procedures, programs, reports and methodologies required under the State EA must be written and implemented.
Schedule B - Water	
B1	Contaminants[37] must not be directly or indirectly released to any waters except as permitted under this environmental authority.
B4	*Schedule B, Table 1 – Authorised works in a watercourse* - permits the ROP2 pipeline outfall location and remedial works within Reach 1- 10 of the ephemeral drainage feature, wetland and outlet watercourse to the Dawson River.

[37] As defined in Section 11 of the *Environmental Protection Act, 1994* (QLD)

Condition #	State EA Requirement
B6	*Schedule B, Table 2 – water release limits for Construction or Maintenance of Linear Infrastructure* – Sets water quality limits for turbidity (NTU) and hydrocarbons for works under condition B4.
B7	Monitoring for must be undertaken at a reasonable frequency to ensure compliance with condition (B6).
B8	Results of impact monitoring carried out under condition (B6) must be included in a register of linear construction and maintenance activities in wetlands and watercourse.
Erosion and sediment control	
B14	Minimise soil erosion from flowing water. Minimise work-related soil erosion and sediment runoff.
B24	Releases must not cause erosion of the bed and banks of the receiving waters or cause a material build-up of sediment in such waters.
CSG contaminant release	
B15	Approved release point for treated water from Reverse Osmosis Plant 2 (ROP2) to a tributary of Dawson River
B16	Release of contaminants to waters from ROP2 must cease on or before 23 July 2026
B17	Must not cause an adverse impact[38] on species richness or species abundance of aquatic fauna
B18	Maximum volume of desalinated water release is 18 ML per day for ROP2
Receiving environment monitoring	
B19	States that release of contaminants must not exceed referenced CL in Schedule B, Table 4 at HCS04DWB01 and Table 5 at S4
B20	Specifies the frequency of monitoring for each quality characteristic (parameter) specified in Schedule B, Table 4 and Table 5.
B21	If boron concentrations at HCS04 DWB pond exceed 2.0 mg/L weekly monitoring of boron must be conducted at S4
B36	Specifies a REMP must be developed to monitor, identify and describe any adverse impacts to surface water environmental values, quality and flows due to the authorised activity and must include periodic monitoring for the effects of the discharge on the receiving environment (under natural flow conditions) as a result of contaminant releases to waters from the site.
B40	The REMP design document must be certified by a suitably qualified person
B41	**Scope and content of the REMP**
(B41) (a)	Description of potentially affected receiving waters including key communities and background water quality characteristics based on accurate and reliable monitoring data that takes into consideration any temporal and spatial variation (e.g. seasonality)
(B41) (b)	Description of applicable environmental values
(B41) (c)	Description of water quality objectives to be achieved
(B41) (d)	Any relevant reports prepared by other governmental or professional research organisations that relate to the receiving environment within which the REMP is proposed
(B41) (e)	Water quality targets within the receiving environment to be achieved, and clarification of contaminant concentrations or levels indicating adverse environmental impacts during the REMP

[38] Not defined in the State EA

Condition #	State EA Requirement
(B41) (f)	Monitoring for any potential adverse environmental impacts caused by the release
(B41) (g)	Monitoring for algal blooms
(B41) (h)	Monitoring of stream flow and hydrology
(B41) (i)	An assessment of bank stability, including monitoring for any potential adverse environmental impacts caused by the release including impacts to bank stability and erosion, and an evaluation of watercourse bank slumping
(B41) (j)	Monitoring of physical chemical parameters as a minimum those specified in Schedule B, Table 4 – Contaminant Limits, Schedule B, Table 5 – Contaminant Limits for Protecting the Environmental Value of Drinking Water and Schedule B, Table 8 – Event-based release-Contaminant monitoring
(B41) (k)	Monitoring biological indicators in accordance ANZECC & ARMCANZ 2000 (including Before, After, Control, Impact (BACI) Principal) and, where possible, consistent with methodologies specified by frc Environmental Pty Ltd in their report titled Santos Coal Seam Gas Fields Aquatic Ecology Impact Assessment
(B41) (l)	Monitoring metals/metalloids in sediments (in accordance with ANZECC & ARMCANZ 2000, A Guide To The Application Of The ANZECC & ARMCANZ Water Quality Guidelines In The Minerals Industry (BATLEY et al) and/or the most recent version of AS5667.1 Guidance on Sampling of Bottom Sediments) for permanent, semi-permanent water holes and water storages
(B41) (m)[a]	Monitoring of a selection of invertebrate species (minimum of three from the local receiving environment) to assess ecosystem health (e.g. exoskeleton density) in respect to the availability of calcium and magnesium
(B41) (n)	The methods for analysis and interpretation all monitoring results
(B41) (o)	The locations of monitoring points (including the locations of proposed background and downstream impacted sites for each release point)
(B41) (p)	The frequency or scheduling of sampling and analysis sufficient to determine water quality objectives and to derive site specific reference values within two (2) years (depending on wet season flows) in accordance with the Queensland Water Quality Guidelines 2009. For ephemeral streams, this should include periods of flow irrespective of mine or other discharges
(B41) (q)	Monitoring of quality characteristics must include the limits specified in Schedule B, Table 4 – Contaminant Limits to assess the extent of the compliance of concentrations with water quality objectives derived through condition (B26)(p)
(B41) (r)	Specify sampling and analysis methods and quality assurance and control
(B41) (s)	Any historical data sets to be relied upon
(B41) (t)	Description of the statistical basis on which conclusions are drawn
(B41) (u)	Any control or reference sites
(B41) (v)	Recording of planned and unplanned releases to watercourses, procedures for event monitoring, monitoring methodology used and procedure to establish background surface water quality
Schedule K - Notification	

Condition #	State EA Requirement
K1	The administering authority must be notified through the Pollution Hotline as soon as reasonably practicable, but within 48 hours after becoming aware of: • any unauthorised significant release of contaminants.
K2	In the event that a drinking water quality parameter limit is exceeded in Schedule B, Table 5 – Contaminant Limits for Protecting the Environmental Value of Drinking Water, the following events must occur within 24 hours of becoming aware of any non-compliance: • the administering authority must be notified on the Pollution Hotline • the holder of this authority must telephone any affected drinking water service provider.
K4	The notification of emergencies or incidents as required by condition K1 must include but not be limitedto the following information: • the environmental authority number and name of the holder • the tenure type and number where the emergency or incident occurred • the name and telephone number of the designated contact person • the location of the emergency or incident (GDA94) • the date and time that the emergency or incident occurred • the date and time the holder of this environmental authority became aware of the emergency or incident • details of the nature of the event and the circumstances in which it occurred • the estimated quantity and type of any contaminants involved in the incident • the actual or potential suspected cause of the emergency or incident • a description of the land use at the site of the emergency or incident (e.g. grazing, pasture, forest etc.) and/or the name of any relevant waters and other environmentally sensitive features • a description of the possible impacts from the emergency or incident • a description of whether stock and/or wildlife were exposed to any contaminants released andmeasures taken to prevent access for the duration of the emergency or incident • any sampling conducted or proposed, relevant to the emergency or incident • landholder details and details of landholder consultation • immediate actions taken to control the impacts of the emergency or incident and how environmental harm was mitigated at the time of the emergency or incident; and • whether further examination/root cause analysis is required and if so, the expected date by when this examination will be completed and reported to the administering authority.
K5	Within 10 business days following the initial notification under conditions (K1), (K2), (K3) and (K4), unless a longer time is agreed to by the administering authority, a written report must be provided to the administering authority, including the following (where relevant to the emergency or incident): • the root cause of the emergency or incident • the confirmed quantities and types of any contaminants involved in the incident • results and interpretation of any analysis of samples taken at the time of the emergency orincident (including the analysis results of any impact monitoring) • a final assessment of the impacts from the emergency or incident including any actual or potential environmental harm that has occurred or may occur in the longer term as a result ofthe release • the success or otherwise of actions taken at the time of the incident to prevent or minimise environmental harm • results and current status of landholder consultation, including commitment to resolve any outstanding issues / concerns • actions and / or procedural changes to prevent a recurrence of the emergency or incident.

9.3 Receiving Environment Monitoring Program

In accordance with State EA condition B36 that requires the development of a REMP to assess if desalinated water releases were having any adverse environmental impact, the Santos Ltd Dawson River Watercourse Release: Receiving Environment Monitoring Program (REMP) has been developed and implemented. The REMP defines the receiving environmental attributes, temporal context of the receiving environment and ongoing monitoring requirements.

Monitoring of water quality, flow characteristics, abiotic and biotic parameters has been undertaken in accordance with the REMP since GLNG desalinated water releases were authorised to commence in 2015.

The monitoring components of the REMP since conception have included monitoring across control, impact and compliance sites (Table 9-1) for:

- Hydrology (stream flow)
- Geomorphology (bed and bank stability)
- Water quality – aquatic ecosystems (physico-chemical parameters, nutrients, metals and metalloids, major ions, algae)
- Water quality – drinking water quality
- Sediment quality
- Biological (macroinvertebrates, fish, zooplankton)

Based on baseline monitoring prior to the commencement of the GLNG project water releases, the State EA did not include baseline data or monitoring for turtles.

The REMP attached as Appendix J has been revised (frc, 2022) to reflect the latest State EA (with effect from 03 November 2022) condition numbering and incorporate additional information in response to IESC review comments. The 2022 REMP updates include:

- presentation of data gathered for the two MNES turtle species known to inhabit waters within and in the vicinity of the action area since 2014
- additional direct visual observation by snorkelling turtle monitoring

The updated REMP design is presented as Table 9-4

The REMP monitoring procedures, reporting and outputs are presented in Table 9-5.

Section 9.4 discusses responses should REMP monitoring results not meet expected or set requirements.

With the inclusion of turtle monitoring and reporting within the REMP, it is proposed this monitoring program captures all necessary data for the proposed action.

Table 9-4 REMP design for Dawson River watercourse releases desalinated releases program

Monitoring Component	Parameter	Monitoring Site	Monitoring Frequency(#1)
Hydrological Components			
stream flow	discharge (m^3/s) and water level (m)	gauging stations (#2) located at receiving environment sites WLMP1, and S4 WLMP1, DRMP1 and control site DRR1	Discharge monitored daily but accessed as needed Visual observations twice per year (notionally pre-wet and post-wet season)
Geomorphology Components			
bed and bank stability	assessment of bed and bank	receiving environment sites WLMP1, WLMP4, WLMP5, DRMP1 and S4; control sites DRR1 and DRR2	twice per year (notionally pre-wet season and post-wet season)
Water Quality Components – Aquatic Ecosystems [a]		**(#3)**	
physico-chemical parameters	temperature, pH, electrical conductivity, turbidity, dissolved oxygen	receiving environment sites WLMP1, WLMP4, WLMP5 and DRMP1; control sites DRR1 and DRR2	twice per year (notionally pre-wet season and post-wet season)
	total suspended solids	receiving environment sites WLMP1, DRMP1 and control sites DRR1 and DRR2	twice per year (notionally pre-wet season and post-wet season)
nutrients	total nitrogen	receiving environment sites WLMP1, WLMP2, WLMP3, WLMP4 and WLMP5 control sites DRR1 and DRR2	twice per year (notionally pre-wet season and post-wet season)
	ammonia	receiving environment sites WLMP1, WLMP2 and WLMP3 control sites DRR1 and DRR2	twice per year (notionally pre-wet season and post-wet season)
metals and metalloids	total and dissolved boron	receiving environment site DRMP1 receiving environment sites WLMP1, WLMP4, WLMP5 and DRMP1; control sites DRR1 and DRR2	weekly during release from ROP2 twice per year (notionally pre-wet season and post-wet season)

Monitoring Component	Parameter	Monitoring Site	Monitoring Frequency(#1)
	dissolved zinc	receiving environment site DRMP1 receiving environment sites WLMP1, WLMP4, WLMP5 and DRMP1; control sites DRR1 and DRR2	weekly during release from ROP2 twice per year (notionally pre-wet season and post-wet season)
	dissolved metals and metalloids (Al, As, Cd, Cr, Co, Cu, Fe, Pb, Mn, Hg, Ni, Se)	receiving environment sites WLMP1, WLMP4, WLMP5 and DRMP1; control sites DRR1 and DRR2	Required if triggered by exceedances
major ions	total Ca, Cl, Fl, Mg, K, Na, SO_4	receiving environment sites WLMP1, WLMP4, WLMP5 and DRMP1; control sites DRR1 and DRR2	Required if triggered by exceedances
algae	visual inspection	receiving environment sites WLMP1, WLMP2, WLMP3, WLMP4 and WLMP5	twice per year (notionally pre-wet season and post-wet season)
Water Quality Components – Drinking Water Quality			
drinking water components	alpha activity, aluminium, ammonia, antimony, arsenic, barium, benzene, beta activity, bisphenol A, boron, bromide, cadmium, chromium, copper, cyanide, ethylbenzene, fluoride, iodide, lead, manganese, mercury, molybdenum, nickel, nonylphenol, PAH (as B(a)P TEF), selenium, silver, strontium, toluene, TPH, vanadium, xylenes, zinc	receiving environment site S4	first release day of each quarter
Sediment Quality Components			
metals and metalloids	total metals and metalloids (As, B, Cr, Cu, Fe, Mn, Ni, Pb, Se, Zn)	receiving environment sites WLMP1, WLMP4, WLMP5, DRMP1 and S4; control sites DRR1 and DRR2	twice per year (notionally pre-wet season and post-wet season)
Biological Components			
threatened turtle species	mean abundance of white-throated snapping turtle; Fitzroy River turtle (monitor only)	receiving environment sites WLMP1, WLMP4, WLMP5, DRMP1 and S4; control sites DRR1 and DRR2	twice per year (notionally pre-wet season and post-wet season)

Monitoring Component	Parameter	Monitoring Site	Monitoring Frequency(#1)
macroinvertebrates	richness of aquatic macroinvertebrate taxa identified to the lowest practical taxonomic level; density of exoskeleton of crustaceans and molluscs	receiving environment sites WLMP1, WLMP4, WLMP5, DRMP1 and S4; control sites DRR1 and DRR2	twice per year (notionally pre-wet season and post-wet season)
fish	richness of species	receiving environment sites WLMP1, WLMP4, WLMP5, DRMP1 and S4; control sites DRR1 and DRR2	twice per year (notionally pre-wet season and post-wet season)
zooplankton	taxonomic diversity; presence of *Ceriodaphnia* cf *dubia*	receiving environment sites WLMP1, WLMP4, WLMP5, DRMP1 and S4; control sites DRR1 and DRR2	twice per year (notionally pre-wet season and post-wet season)

(#1) If unsafe conditions (e.g. river flows following rain events) prevent the safe application of the procedures (e.g. fish/turtle netting), the frequency of monitoring components may be altered.

The frequency of monitoring may also be altered if no release occurs in the 6 month period related to each pre-wet and post-wet schedule.

REMP monitoring is proposed to cease two years post cessation of the desalinated releases (i.e. 4 monitoring rounds completed after releases cease).

Some sites (e.g. WLMP4) may be dry in some surveys, depending on factors such as antecedent rainfall. Where sites are dry, bank stability and sediment quality will still be sampled during the desalinated release monitoring program.

(#2) Gauging stations may be damaged or destroyed during flood conditions resulting in a data gap until equipment can be replaced or repaired.

(#3) Only water quality monitoring relating to the receiving environment is presented within the REMP monitoring program.

Table 9-5 REMP monitoring procedures

Methodology	REMP Outputs / Reporting / Trigger Action/Response
Hydrological – stream flow and water depth	
Daily by automated gauging stations located at receiving environment sites WLMP1, and S4	Hydrographs of the release volumes recorded at the discharge location and stream flow data recorded at gauging stations will be produced for the entire year.
Geomorphological Component – Bank Stability	
Bank stability will be monitored using the Sustainable Rivers Audit physical habitat methodology (MDBC 2004a), which is consistent with the methodology used in the Environmental Impact Statement (EIS) for the Santos GLNG Project (which includes the FPA) and the methods used in the baseline surveys. The assessment will include characterisation of the following bank features at each site: • bank shape • bank stability, noting areas of erosion or bank failure • bed stability • artificial bank protection measures • factors affecting bank stability • valley shape • channel shape, and • channel and wetted width. • A visual record of the left and right banks at each site will be made using photographs, with left and right banks determined while facing downstream	Results of field observations of bank stability will be tabulated for each site along with comments about the stability of the bank, and any changes of bank stability over time. Photographs of banks at each site will also be included in bank stability reporting for each survey.
Sediment Monitoring	
Where the water is shallow (<0.5 m deep), sediment samples will be collected from the top 0.30 m of sediment on the bed using a stainless-steel trowel, with the sediments transferred directly into the sampling jar provided by a NATA accredited analytical laboratory. Where the water is deep or the sediment is too soft to walk in, surface sediment from the bed (to 0.30 m depth) will be collected using a stainless-steel corer. Any core samples will be emptied into a bucket or other intermediate container, which has been thoroughly washed with ambient site water prior to sampling. The sediment will be mixed thoroughly and placed into the sample jar using a stainless-steel trowel. Field sampling will be undertaken by a suitably trained and competent person in accordance with Australian / New Zealand Standard AS/NZ5667.12 Guidance on Sampling of Bottom Sediments, and the Handbook for Sediment Quality Assessment (Simpson et al. 2005). In summary:	Sediment quality data will be entered, and the results reviewed after each survey. This review will include comparisons of sediment quality at each site with the local sediment quality guidelines to give preliminary indication of any changes to sediment quality in the receiving environment. **ACTION/RESPONSE** • If the concentration of a parameter is below the local sediment guideline, then sediment quality is considered to be low risk for that parameter and no further action is required. • If the concentration of a parameter is higher than the local guideline, then further investigation of background levels for that parameter in the area would be required.

Methodology	REMP Outputs / Reporting / Trigger Action/Response
• powderless gloves will be used when collecting all sediment samples, and care will be taken not to touch the inside of any sampling containers, or to place open bottles / jars or their lids onto the ground or other potentially contaminated surfaces • sediment samples will be collected straight into the sample bottle wherever possible, and the bottles will not be rinsed prior to sample collection • if the sample cannot be collected straight into the sample bottle, the container it is collected in (such as a stainless-steel bucket or other form of sampler) will be thoroughly rinsed with ambient site water to ensure is not contaminated • a field duplicate will be collected from one site during each sampling event, to assess within site variation • samples will be placed into an esky with ice and should be kept refrigerated until delivered to the laboratory within the appropriate holding time (as advised by the analytical laboratory) • a chain of custody form will be completed for all samples sent to the laboratory for analysis, and • samples will be analysed by a NATA-accredited laboratory, and laboratory duplicates will be analysed in accordance with NATA-accredited protocols.	At the end of each annual reporting period, the median, 80th percentile and 100% percentile for each parameter for each water type will be calculated and compared to the local sediment quality guidelines. **ACTION/RESPONSE** • If the median concentration of a parameter is below the local sediment guideline, then sediment quality is considered to be low risk for that parameter and no further action is required. • If the median percentile concentration of a parameter is higher than the local guideline, then further investigation of background levels for that parameter in the area would be required. • If the median percentile concentration of a parameter is consistently higher than the local guideline, then further investigation of background levels for that parameter in the area would be required. • If the 80th percentile concentration of a parameter is consistently higher than the local guideline, then further investigation of background levels for that parameter in the area would be required. • If the 100% percentile concentration of a parameter is higher than the 100% percentile of baseline data, then further investigation of factors affecting the bioavailability of that parameter may be required (ANZG 2018).
Macroinvertebrate Monitoring	
Seven macroinvertebrate samples will be collected from ‘clean’ edge habitat at each site using a Surber sampler that has a square 0.3 m x 0.3 m frame and 250 µm mesh size. The location of samples will be random within each site. Each sample will be collected with one edge of the Surber sampler parallel to and within a few centimetres of the water’s edge. The substrate within the Surber sampler frame will be disturbed (large rocks will be cleaned or organisms inside the Surber net and finer substrates will be gently disturbed by hand or a tool) and the sample will be collected by sweeping the net up through the disturbed area. The sample will be transferred into a screw-top jar and preserved using ethanol to be transported back to the laboratory and identified to the lowest practical taxonomic level (family in most cases).	Macroinvertebrate samples will be processed in accordance with the National River Health Program protocols outlined in Monitoring and Sampling Manual 2009 (DERM 2009). Enumeration and identification of samples will be done by trained and accredited ecologists. Sorting, enumeration and data entry will be cross checked by a second ecologist for 10% of the samples. An error rate of > 10% will be considered unacceptable and will result in a further 10% of samples being checked by a second ecologist, and so on.

<table>
<tr><th>Methodology</th><th>REMP Outputs / Reporting / Trigger Action/Response</th></tr>
<tr><td>Macroinvertebrate sampling will be undertaken by a trained ecologists and will be completed in accordance with the Smart Rivers methodology (Smart Rivers 2013).
Individuals from two of the commonly occurring invertebrate species (Macrobrachium australiense and Caridina spp.) will be examined for signs of potential calcium and magnesium deficiencies: the strength, apparent thickness and colour of the exoskeletons and shells will be recorded, and the reproductive status of specimens will be recorded.</td><td></td></tr>
<tr><td>The following indices will be calculated for the macroinvertebrate communities at each site:
abundance; abundance is the total number of individuals in a sample. The abundance of each family, and the overall abundance of macroinvertebrates, will be calculated for each site.
taxonomic richness; taxonomic richness is the number of taxa (in this assessment, generally families). Taxonomic richness is a basic, unambiguous and effective diversity measure. However, it is affected by arbitrary choice of sample size. Where all samples are of equal size, taxonomic richness is a useful tool when used in conjunction with other indices. Richness does not take into account the relative abundance of each taxon, so rare and common taxa are considered equally.
PET richness; while some groups of macroinvertebrates are tolerant to pollution and environmental degradation, others are sensitive to these stressors (Chessman 2003). Plecoptera (stoneflies), Ephemeroptera (mayflies), and Trichoptera (caddisflies) are referred to as PET taxa, and they are particularly sensitive to disturbance. There are typically more PET families within sites of good habitat condition and water quality than in sites of degraded condition. PET taxa are often the first to disappear when water quality or environmental degradation occurs (EHMP 2007). The lower the PET score (i.e. number of families within the Plecoptera, Trichoptera and Ephemeroptera orders), the greater the inferred degradation.
SIGNAL-2 scores; SIGNAL-2 (Stream Invertebrate Grade Number — Average Level) (Chessman 2003) scores are also based on the sensitivity of each macroinvertebrate family to pollution or habitat degradation. Each macroinvertebrate family has been assigned a grade number between 1 and 10 based on their sensitivity to various pollutants, and SIGNAL-2 scores are weighted for abundance. A low number means that the macroinvertebrate is tolerant of a range of environmental conditions, including common forms of water pollution (e.g. suspended sediments and nutrient enrichment).</td><td>These indices will be calculated for each site, and the median for each calculated for each water type. Where the median for an index complies with or is higher than the local biological guideline for that water type, then it is considered that there is no impact to macroinvertebrate communities.

ACTION/RESPONSE
Where the median for an index is lower than the local biological guideline for a water type, then multivariate statistical analysis of macroinvertebrate data that conforms to a before-after-control-impact (BACI) design may be needed.
Where this test indicates an impact to macroinvertebrate communities in the receiving environment, then further investigation to the factors that influence macroinvertebrate communities may be needed.</td></tr>
<tr><td colspan="2">Fish</td></tr>
</table>

Methodology	REMP Outputs / Reporting / Trigger Action/Response
Fishing will involve two fyke nets set overnight at each site, with one net being of fine mesh size (approximately 4 mm) and the other being of a larger mesh size (approximately 10 mm). Nets will be set facing upstream and downstream directions at all sites, and nets will be set to ensure that air-breathing species (e.g. turtles) have access to the surface at all times, with floats also used to ensure air-breathing species can access the surface. The sampling of fishes will be conducted under appropriate General Fisheries Permits and Animal Ethics Approvals. At each site, the species present and the abundance of each species by life history stage (juvenile, intermediate, adult) will be recorded and the apparent health of individuals will be noted. Identifications of fish will be made in the field by experienced ecologists. Specimens that cannot be identified in the field will be euthanized and returned to the laboratory for identification and, if necessary, they will be sent to the Queensland Museum for a confirmed identification. Any exotic species caught will be recorded and euthanized in accordance with ethics approvals.	The richness of native and exotic fish species will be determined for each water type (observed number of species), and this will be compared to the expected number of species for that water type (i.e. the local biological guideline for fish) as a ratio. Where the ratio ≥ 1, then it is considered that there has been no impact to fish. **ACTION/RESPONSE** • Where ratio is < 1, then the diversity of fish is lower than expected, and an investigation of the factors affecting fish communities may be needed.
Turtles	
Survey of turtles will involve two fyke nets set overnight at each site, with one net being of fine mesh size (approximately 4 mm) and the other being of a larger mesh size (approximately 10 mm). Nets will be set facing upstream and downstream directions at all sites, and nets will be set to ensure that air-breathing species (e.g. turtles) have access to the surface to breathe at all times, with floats also used to ensure air-breathing species can access the surface. Additionally, two baited cathedral traps will be securely set over-night at each site, ensuing turtles and other air-breathing species have access to the surface to breathe at all times. Finally, snorkelling the full 100 m length of each site will also be used to survey turtles, recording observations of turtles. The sampling of turtles will be conducted under appropriate Scientific Permits and Animal Ethics Approvals. At each site, the species present and the abundance of each species will be recorded and the apparent health of individuals will be noted. Identifications of turtles will be made in the field by experienced ecologists.	Raw data for all turtle species will be tabulated and compared to baseline data.

9.4 Summary of State EA and REMP management responses

The continuation of ongoing REMP monitoring is designed to identify potential changes within the receiving environment and trigger a management response in accordance with the REMP and State EA.

Should the monitoring programs described in Section 9.2 and Section 9.3 present data that is either in non-compliance with set compliance targets (e.g. State EA CL or WQOs) or detects potential adverse impacts to the environment, the response will be guided by responses documented within the requirements of the *Environmental Protection Act, 1994* (QLD), State EA and REMP and/or appropriate to the level of impact identified for the incident.

The Dawson River Desalinated Release REMP has a two-tier approach to detecting adverse environmental impacts on the receiving aquatic ecosystem:

1. Tier 1: an investigation would be triggered where there is a non-compliance with any of the local WQGs for water quality, sediment quality and / or biological parameters at any receiving environment monitoring site. The approach would include:
   - a root cause review of the exceedances with appropriate corrective / preventative actions
   - a review of any other available information, such as non-project site specific influences, and
   - reporting in accordance with the State EA.
2. Tier 2: a response will be triggered where the results of the Tier 1 approach indicate a potential impact to the receiving environment. The Tier 2 response would include:
   - rapidly re-sampling relevant parameters at appropriate monitoring locations to ensure the data is representative, and
   - response and reporting in accordance with Santos' SMS-HSS-OS05-PD01 – Crisis, Incident Management & Emergency Response Procedure and State EA Conditions K1 to K4.

Table 9-6 Summary of required Management responses and actions

Item	State EA/REMP Response or action
Hydrological water quality	
State EA Schedule B1 Release of contaminants to waters	Contaminants must not be directly or indirectly released to any waters except as permitted under this environmental authority.
State EA Schedule B21 Boron concentration in water at HSC04DWB1 exceeds 2.0 mg/L.	Complete weekly monitoring for boron must be undertaken at S4
State EA Schedule B22 Boron concentration at S4 is between 1.2 mg/L and 1.5 mg/L	All third parties that undertake irrigation using water from the Dawson River, up to a distance of 20km downstream of S4, must be notified
State EA Schedule B22 Boron concentration at S4 exceeds 1.5 mg/L	All third parties downstream of S4 that undertake irrigation using water from the Dawson River upstream of the Glebe Weir (coordinates: - 25.4647, 150.0349), must be notified
State EA Schedule K1 Occurrence of an environmental incident	The administering authority must be notified through the Pollution Hotline as soon as reasonably practicable, but within 48 hours after becoming aware of: a) any unauthorised significant disturbance to land; or b) any unauthorised release of contaminants greater than: (i) 200 L of hydrocarbons; or (ii) 200 L of stimulation additives; or (iii) 500 L of stimulation fluids; or (iv) 1,000 L of brine; or

	(v) 5,000 L of coal seam gas water; or (vi) 10,000 L of sewage effluent; (vii) 100,000 L of irrigation-quality coal seam gas water, released inside a designated irrigation area authorised by condition (C8)(c). c) a potential or actual loss of structural or hydraulic integrity of a dam; or d) when the level of the contents of any regulated dam reaches the mandatory reporting level; or e) when a regulated dam will not have available storage to meet the design storage allowance on the 1 November of any year; or f) any incident where there is a potential or actual loss of well integrity (e.g. when the annulus pressure during stimulation increases by more than 3.5 MPa from the pressure immediately preceding stimulation); or g) any detection of restricted stimulation fluids from stimulation fluid monitoring; or h) any analyses result from baseline bore, well or stimulation impact monitoring that exceeds a water quality objective for the protection of an environmental value of that water resource; or i) any analyses result from groundwater monitoring that exceeds trigger action investigation levels, if provided in this environmental authority.
State EA Schedule K4 Notification requirements of an emergency or incident	The notification of emergencies or incidents as required by condition K1 must include but not be limited to the following information: (a) the environmental authority number and name of the holder (b) the tenure type and number where the emergency or incident occurred (c) the name and telephone number of the designated contact person (d) the location of the emergency or incident (GDA94) (e) the date and time that the emergency or incident occurred (f) the date and time the holder of this environmental authority became aware of the emergency or incident (g) details of the nature of the event and the circumstances in which it occurred (h) the estimated quantity and type of any contaminants involved in the incident (i) the actual or potential suspected cause of the emergency or incident (j) a description of the land use at the site of the emergency or incident (e.g. grazing, pasture, forest etc.) and/or the name of any relevant waters and other environmentally sensitive features (k) a description of the possible impacts from the emergency or incident (l) a description of whether stock and/or wildlife were exposed to any contaminants released andmeasures taken to prevent access for the duration of the emergency or incident (m) any sampling conducted or proposed, relevant to the emergency or incident (n) landholder details and details of landholder consultation (o) immediate actions taken to control the impacts of the emergency or incident and howenvironmental harm was mitigated at the time of the emergency or incident; and (p) whether further examination/root cause analysis is required and if so, the expected date by when this examination will be completed and reported to the administering authority.

State EA Schedule K5 Incident Reporting Requirements	Within 10 business days following the initial notification under conditions (K1), (K2), (K3) and (K4), unless a longer time is agreed to by the administering authority, a written report must be provided to the administering authority, including the following (where relevant to the emergency or incident): (a) the root cause of the emergency or incident (b) the confirmed quantities and types of any contaminants involved in the incident (c) results and interpretation of any analysis of samples taken at the time of the emergency orincident (including the analysis results of any impact monitoring) (d) a final assessment of the impacts from the emergency or incident including any actual or potential environmental harm that has occurred or may occur in the longer term as a result ofthe release (e) the success or otherwise of actions taken at the time of the incident to prevent or minimise environmental harm (f) results and current status of landholder consultation, including commitment to resolve any outstanding issues / concerns (g) actions and / or procedural changes to prevent a recurrence of the emergency or incident.
Geomorphological Component – Bank Stability	
State EA Schedule B24 Erosion of bed and banks or sediment accumulation	Releases to waters must be undertaken so as not to cause erosion of the bed and banks of the receiving waters, or cause a material build-up of sediment in such waters
Sediment	
REMP Section 8.1.1 Review of sediment quality data against Local Trigger value for each sampling event and annually	**Sampling Event** (a) If the concentration of a parameter is below the local sediment guideline, then sediment quality is considered to be low risk for that parameter and no further action is required. (b) If the concentration of a parameter is higher than the local guideline, then further investigation of background levels for that parameter in the area would be required. **Annually** (a) If the median percentile concentration of a parameter is higher than the local guideline, then further investigation of background levels for that parameter in the area would be required. (b) If the median percentile concentration of a parameter is consistently higher than the local guideline, then further investigation of background levels for that parameter in the area would be required. (c) If the 80th percentile concentration of a parameter is consistently higher than the local guideline, then further investigation of background levels for that parameter in the area would be required. (d) If the 100% percentile concentration of a parameter is higher than the 100% percentile of baseline data, then further investigation of factors affecting the bioavailability of that parameter may be required (ANZG 2018).
Invertebrates/Crustacean Carapace Monitoring	
REMP Section 8.1.2 Individuals from two of the commonly occurring invertebrate species (*Macrobrachium australiense* and *Caridina spp*.) will be examined for	Monitoring requirement only

signs of potential calcium and magnesium deficiencies: the strength, apparent thickness and colour of the exoskeletons and shells will be recorded, and the reproductive status of specimens will be recorded.	
Macroinvertebrate Monitoring	
REMP Section 8.1.2 Review of macroinvertebrate indices (abundance, richness, PET richness and SIGNAL-2 score) as the mean of seven edge locations	(a) Where the median for an index complies with or is higher than the local biological guideline for that water type, then it is considered that there is no impact to macroinvertebrate communities. (b) Where the median for an index is lower than the local biological guideline for a water type, then multivariate statistical analysis of macroinvertebrate data that conforms to a before-after-control-impact (BACI) design may be needed. (c) Where this test indicates an impact to macroinvertebrate communities in the receiving environment, then further investigation to the factors that influence macroinvertebrate communities may be needed.
Fish	
REMP Section 8.1.3 The richness of native and exotic fish species will be determined for each water type (observed number of species), and this will be compared to the expected number of species for that water type (i.e. the local biological guideline for fish) as a ratio.	(a) Where the ratio ≥1, then it is considered that there has been no impact to fish. (b) Where is ratio < 1, then the diversity of fish is lower than expected, and an investigation of the factors affecting fish communities may be needed.

10.0 Ecologically sustainable development

Australia's National Strategy for Ecologically Sustainable Development (Ecologically Sustainable Development Steering Committee, 1992) defines ecologically sustainable development (ESD) as: 'using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased'. The EPBC Act (Section 3A) defines principles of ecologically sustainable development as:

- Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations.
- If there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.
- The principle of inter-generational equity—that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.
- The conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making.
- Improved valuation, pricing and incentive mechanisms should be promoted.

Project implementation of the ecologically sustainable development principles are reviewed in Table 10-1.

Table 10-1 Project implementation of the principles of ecologically sustainable development

Principle	Project implementation
Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations	Santos maintains an advanced environmental, health and safety management system that comply with Australian Standards AS/NZS4801:2001 and ISO14001:2015. All staff, contractors, and subcontractors, are required to: • Comply with all requirements of environmental legislation • Comply with specific requirements of the Environmental Authority and associated approvals/licenses • Undertake all activities in accordance with the agreed management plans, procedures, work method statements and safe work method statements • Ensure that they are aware of the contact person regarding environmental matters • Report any activity that has resulted in, or has the potential to result in an environmental incident or non-compliance • Participate in investigations and undertaking corrective actions (where required) to reduce or remediate environmental harm or to prevent the re-occurrence of an incident, and • Ensure that they attend any environmental training provided The following protocol, in order of preference, is used to determine the appropriate course of action when assessing potential impacts and environmental risks. This process is implemented in all stages of construction from conception and design, through site selection and construction and into rehabilitation and decommissioning. • Avoid – avoid direct and indirect impacts • Minimise – minimise potential impacts • Mitigate – implement mitigation measures to manage the risks of adverse impacts • Remediate and rehabilitate – actively remediate and rehabilitate impacted areas, and • Offset – offset residual adverse impacts in accordance with regulatory requirements Santos is committed to creating a sustainable future for the communities in which it operates, by providing local employment, training, education and enterprise opportunities. This commitment includes partnering with community groups and organisations that contribute to the social vitality of the region and work with local businesses and organisations to create jobs, build diverse skill sets and keep Santos' supply chain local. Keeping Santos' supply chain local is a key enabler for economic, environmental, social and operational sustainability. Hiring and procuring locally is important to Santos because it encourages: • A reliable, local supply chain that can be flexible and resilient in times of uncertainty • Long-term socio-economic benefits for smaller regional communities • Upskilling and educational opportunities, and • Local suppliers to source from other local companies Sharing the positive economic and social benefits of natural gas is critical to ensuring a sustainable future for both Santos and the community.

<table>
<tr><th>Principle</th><th>Project implementation</th></tr>
<tr><td>If there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. If there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation</td><td>The precautionary principal is considered in all phases of Project development from preliminary design, through to construction, decommissioning and rehabilitation. Santos' impact assessment approach assumes that identified impacts will occur, thus enabling worst-case scenarios to be identified, assessed and mitigated within a continuous improvement context.

This approach will be maintained throughout all phases of the Project, providing multiple opportunities for refinement of scope and execution to reduce impacts and scientific uncertainty.</td></tr>
<tr><td>The principle of inter-generational equity - that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations</td><td>As stated above, Santos is committed to creating a sustainable future for the communities in which it operates, by providing local employment, training, education and enterprise opportunities. Keeping Santos' supply chain local is a key enabler for economic, environmental, social and operational sustainability. Sharing the positive economic and social benefits of natural gas is critical to ensuring a sustainable future for both Santos and the community.

Minimising potential environmental impacts is a key consideration for Project development. This will ensure that environmental values (including MNES and groundwater resources and quality) are conserved for existing and future generations.

Whilst recognising that LNG projects are still a contributing factor in total global emissions, Santos believes it can play a key role in driving decarbonisation and aiding the transition into future and renewable sources of energy. Furthermore, Santos has an internal strategy to transform, build and grow in an aim to position the business to achieve its vision to be Australia's leading natural gas company by 2025. To deliver this vision, Santos aims to:

• Reduce emissions and improve air quality across Asia and Australia, by displacing coal with natural gas and supporting the economic development of combined gas, clean fuels and carbon capture and storage (CCS) solutions, and
• Be the leading national supplier of domestic gas in Australia

When project activities are complete progressive rehabilitation of areas of disturbance will be designed to achieve three overarching objectives. These are:
• Ensure sites are left as safe, stable, non-polluting landform for humans, native fauna and livestock
• Minimise loss of land capability within agricultural areas, and
• Assist in the minimisation of long-term impacts to environmentally sensitive areas and MNES including TEC and threatened species habitat

Santos will conduct regular monitoring and inspections of rehabilitated and remediated areas to ensure maintain the appropriate trajectory to meet the criteria above and undertake maintenance measures where required.</td></tr>
</table>

Principle	Project implementation
The conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making	Santos has developed a comprehensive environmental management and assessment framework to minimise impacts on biological diversity and ecological integrity. This framework remains informs decision regarding proposed Project activities in all phases of the Project. Principally, this is achieved through: • designing of the project to avoid or minimise impacts on existing environmental values wherever practicable • implementation of the constraints protocol requirements prior to disturbance of new ground, and • commitment to implement best practice environmental management and mitigation measures through all phases Project (construction, operation and decommissioning) commensurate to the level of risk posed by the Project In particular site selection protocols are designed to: • avoid disturbance to threatened species as far as practicable • minimise fragmentation and habitat disturbance of protected species • implementation of proven management systems and pollution control measures which will be refined overtime based on: - pre-disturbance data gathered in the field - experience, and - monitoring data
Improved valuation, pricing and incentive mechanisms should be promoted	Consistent with the polluter pays principle, the costs associated with environmental commitments will be incorporated into the overall Project planning and operation costs throughout the full life cycle of the Project. For example: • Scientific/engineering studies and surveys, field assessments and further ecological and hydrological assessments as the Project progresses • Development and implementation of constraints protocol requirements including implementation of design changes and changes to the siting of infrastructure to ensure protection of environmental values • Procedures, equipment and resources required to manage and monitor specific environmental risks such as, produced water, air quality chemical risk and erosion and sediment control • Provisions for rehabilitation and implementation of progressive rehabilitation and monitoring programs • Engagement with community members and stakeholders and provisions for making good and implementing negotiated agreements with landowners and relevant indigenous parties, and • Engagement or staff on contractors to oversee the implementation of Project commitments including legislative and approval requirements A range of mitigation measures will also be implemented to ensure that, during construction and operation, waste is avoided, reused or recycled wherever possible.

Santos supports these principles and is committed to ensuring its activities align with the objectives and principles contained within the strategy. In line with this, Santos has announced ambitious emissions reduction targets in line with global aspirations to limit temperature rises to below 2°C that include:

Scope 1 and 2 emissions reduction targets:

- 2025: Economically reduce emissions by more than five per cent across operations in the Cooper Basin and Queensland (current at the 2016-17 baseline) by 2025
- 2030: Reduce Scope 1 and 2 emissions and emissions intensity by 26-30 per cent by 2030, and
- 2040: Reduce Scope 1 and 2 emissions to net-zero by 2040.

Technology targets:

- 2025: Carbon Capture and Storage (CCS): Pursue step-change emissions reductions technology by assessing the feasibility and, if feasible, invest in technology and innovation which can deliver a step-change in emissions, and
- 2030: Once regulatory matters are finalised, use CCS technology to accelerate the economic feasibility of clean hydrogen and deliver a step-change in emissions reduction.

Scope 3 targets:

- 2025: Reduce global emissions through LNG export growth by growing LNG exports to at least 4.5 million tonnes per annum, and
- 2030: Work with customers to reduce their Scope 1 and 2 emissions by more than one million tonnes CO_2 equivalent per annum by 2030 through direct fuel switching to cleaner fuels.

Across Santos' operations, emissions are being successfully reduced through a suite of initiatives in energy efficiency, electrification, integration of renewables and nature-based carbon offsets. There is also a clear, tangible pathway to reach new goals, with existing and planned initiatives including the step-change technology of CCS, integration of renewable energy sources, electrification, world-class nature-based offsets, energy efficiency and eventually, zero emission hydrogen.

10.1 Ecologically sustainable development and the proposed action

The principles of ecologically sustainable development are demonstrated by proposing cleaner production techniques, waste minimisation and best practice environmental management programs.

In consideration of ecologically sustainable development, a suite of feasibility assessments of potential coal seam water management options, giving due consideration to the Governments CSG Water Management Policy 2012, has been undertaken by Santos. The preferred options for the management of CSG water include the beneficial use of produced water, blended or treated water for irrigation together with construction and operational activities. CSG water management will also involve the release of desalinated water to the Dawson River, with extensive hydrological and ecological studies showing that this release can be carried out without impacting on the environmental values of the Dawson River.

11.0 Conclusion

The proposed action is for the continued release of up to 18 ML/day of desalinated water to the Dawson River via a drainage feature, waterhole and outlet watercourse to the Dawson River.

There will be no increase in the existing approved maximum daily release rate of 18 ML/day or total annual volume of 6,570 ML/year (limited by the State Environmental Authority). GFD Project water will substitute GLNG Project water, and other water management and beneficial use options such as irrigation will remain in place. The GFD Project water will simply form a component of the maximum volume of produced water currently authorised to be released.

Water management and treatment prior to the proposed action will use existing water management and water treatment infrastructure at Hub Compressor Station 04, including the reverse osmosis plant, water storage ponds and desalinated water release pipe from HCS04 to the drainage feature.

The purpose of this updated preliminary documentation (Rev. B) is to provide additional information requested by DCCEEW and the IESC to assess if the proposed action (release of desalinated water) has a significant impact on MNES protected under Part 3 of the *Environmental Protection and Biodiversity Conservation Act, 1999* (Commonwealth), in particular the following:

- listed threatened species (White-throated snapping turtle and Fitzroy River turtle)
- groundwater dependent ecosystems utilised by the listed species or considered a threatened ecological community (TEC)
- a water resource in relation to coal seam gas development.

Assessment of potential impacts to these MNES together with applicable elements of the IESC checklist was completed referencing long term empirical data collected from baseline and REMP monitoring data as required under the State EA, additional survey conducted for the PD, empirical calculations, and where applicable historical modelling.

Potential impacts of the proposed action on groundwater resources, surface water resources including water quality, sediment quality, flow, stream hydraulics, geomorphology, ecology and GDE in the waterhole catchment and Dawson River were assessed against the relevant EPBC significant impact criteria including:

- Significant Impact Guidelines 1.1 (Matters of National Environmental Significance)
- Significant Impact Guidelines 1.3 (Coal seam gas and large coal mining developments – Impacts on water resources).

The significant impact assessment determined that there are unlikely to be impacts to listed threatened species or threatened ecological communities (including groundwater dependent ecosystems), or associated ecosystem functionality from the proposed action.

As such, the proposed action is considered unlikely to directly or indirectly result in a significant change to the specified MNES or hydrological characteristics and water quality of a water resource and its associated ecological habitat requirements that is of sufficient scale or intensity as to reduce the current or future utility of the water resource for third party users (including applicable environmental values and other public benefit outcomes), or to create a material risk of such reduction in utility occurring.

Current monitoring and actions required under the State EA and REMP are considered to be suitable for the proposed action with the addition of refined turtle survey methods to better calculate MNES turtle numbers within the proposed action area.

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Appendix A

DAWE RFI

Appendix B

DAWE RFI Cross Reference Table

Appendix C

IESC Checklist and IESC Comment Response

Appendix D

Environmental Authority
EPPG00928713

Appendix E

Water and Sediment Quality Summary Statistics

Appendix F

REMP Annual Reports

Appendix G

BOOBOOK 2021. Dawson River Groundwater Dependent Ecosystem Assessment

Appendix H

BOOBOOK 2021. Habitat Survey and Impact Assessment for White-throated snapping turtle and Fitzroy River turtle

Appendix I

Chemical Risk Assessment Framework and Chemical Risk Assessment Tables

Appendix J

Dawson River Water Course Release Receiving Environment Monitoring Program